Image Cover Sheet

CLASSIFICATION	SYSTEM NUMBER 144780
UNCLASSIFIED	

TITLE

THE APPLICATION OF HUMAN FACTORS ENGINEERING IN CF CCIS PROJECTS

AN:95-00098

System Number:

Patron Number:

Requester:

Notes:

DSIS Use only:

Deliver to: JR

National Defence Défense nationale

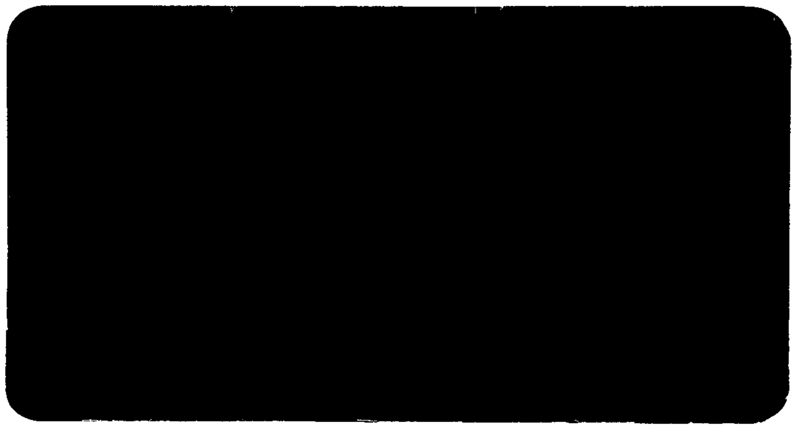
Canada

[redacted]

Defence and Civil INSTITUTE OF ENVIRONMENTAL MEDICINE

INSTITUT DE MEDECINE ENVIRONNEMENTALE pour la défense

1133 Sheppard Avenue West, PO Box 2000, North York, Ontario, Canada M3M 3B9
Tel. (416) 635-2000 Fax. (416) 635-2104



July 1994

DCIEM No. 94-33

THE APPLICATION OF HUMAN FACTORS ENGINEERING IN CF CCIS PROJECTS

D. Beevis*
P. Essens **
I. Mack*

Defence and Civil Institute of Environmental Medicine
1133 Sheppard Avenue West, P.O. Box 2000
North York, Ontario
Canada M3M 3B9

* in alphabetical order
** on exchange from the TNO Human Factors Research Institute, Soesterberg, The Netherlands

EXECUTIVE SUMMARY

This report discusses the problems of integrating Human Factors Engineering (HFE) into the process of developing Command, Control, and Information Systems (CCIS). User acceptance of CCIS has often been problematical, and reasons quoted for such problems include lack of understanding of user requirements and user capabilities. A workshop was organized to discuss the application of HFE in the development of command and control information systems for the Canadian Forces (CF). The workshop concluded that a user-centred approach should be taken to CCIS development, and that a generic Human Engineering Programme Plan (HEPP) should be developed to support project management of HFE in CCIS.

The DND Defence Programme Management System (DPMS) includes the phases: Project Planning, Project Development, and Implementation. The application of HFE is part of the Human Systems Integration (HSI) process which should begin in the Project Planning stages. The DND Project Manager's Handbook covers HFE in an Annex to the chapter on Systems Engineering but it does not mention HFE in the chapter on software development. DND software development projects are usually guided by US DOD-STD-2167A which does not address HFE directly, although various HFE regulatory documents are cross-referenced within it.

Opportunities for the integration of HFE in the software engineering process are provided by new system design methods. METHOD/1™, a system development methodology published by Andersen Consulting, provides a detailed decomposition of tasks performed in system design to which HSI and HFE tasks could be added relatively easily. Object-oriented design localizes information around entities referred to as objects. This approach allows the human to be considered as part of the system, with the possibility of including human attributes such as cognitive work style. Existing HFE analysis techniques share an object-oriented approach with this method of software engineering.

User-centred development is becoming popular as an approach to the development of information systems, and several variants have arisen. The common elements include user involvement, iterative development based on prototyping, and testing against usability criteria. User involvement includes identifying requirements, prioritizing design objectives, evaluating prototypes, and establishing validation criteria. Prototyping is a key feature of the user-centred development process. A prototype provides the means for users and system designers to reach a common understanding of system requirements. At different stages of the system design, prototypes provide the opportunity for making design decisions and evaluations. Prototyping is not without its risks. When poorly planned and implemented, prototypes will fail and will delay a project. Prototyping should be used as a complement to analysis and not as a replacement for it.

Within any project, HFE analysis, experiment, design, and test and evaluation activities are governed by the project Human Engineering Programme Plan (HEPP). The HEPP defines the requirements for applying human engineering to a project, including integration with system engineering. A generic HEPP for CCIS can be based on the US specification for the application of HFE, US MIL-H-46855B. Work items in a generic HEPP include: stakeholder identification, requirements development, analysis, design, interface specification, prototyping, iterative development, and testing. An HEPP also details the relationship of HFE to other activities, provides a list of deliverables, and includes a plan for review meetings. A generic HEPP will invoke various regulatory and guidance documents.

Details of modifications which should be made to MIL-H-46855B for use in CCIS development are provided in the report.

In conclusion, a case can be made for the integration of HFE in DND CCIS projects. Difficulties arise in integrating HFE with system engineering because the documented approaches to software development do not address HFE sufficiently. New approaches to software engineering and a user-centred approach provide a promising combination for improving the situation. The key to a user-centred approach is prototyping, and the effective implementation of a user-centred approach depends on a HEPP. The specification US MIL-H-46855B provides a good framework for developing a generic HEPP.

ABSTRACT

The importance of integrating Human Factors Engineering with the development of Command, Control and Information Systems (CCIS) is discussed. It is recommended that a user-centred approach be taken to the development of such systems. The essential features of four software development approaches are reviewed. It is concluded that current approaches do not facilitate taking a user-centred approach, but new software system design methods provide may do so. The essential features of a user-centred approach are outlined, and the contribution of prototyping is reviewed. Modifications to an existing Human Engineering Programme Plan, US MIL-STD-46855B, are suggested, to provide the basis for a plan for a user-centred approach in CCIS.

TABLE OF CONTENTS

INTRODUCTION

The Department of National Defence (DND) is involved in the development of a number of computer-based command and control systems, known as Command, Control and Information Systems (CCIS). It is estimated that up to 45% of software development costs are associated with the user interface (Nielsen, 1993). Yet, there have been many problems with user acceptance and the ease of use of CCIS (see Hendricks et. al., 1983, for example) and commercial Information Technology (IT) systems. These problems can be addressed through the application of human factors engineering (HFE) [1], which contributes to human systems integration (HSI) (US DoD, 1991). This report addresses the application of HFE to CCIS acquisition, in a user-centred approach, to avoid such problems.

A number of reasons have been cited for problems in the development of CCIS and IT systems, including lack of understanding of users' requirements and capabilities (see Rouse, 1991, for example). Understanding users' requirements is difficult, because the behaviour of any new system is emergent, depending on the interaction between what technology dictates that the users do and what the users do to exploit the technology. The introduction of new technology changes the users' understanding of what they can do and what they need. So user requirements for complex man-machine systems are often subjective, vague, incomplete, or unknown (McLaughlin, 1987; Pressman, 1987).

Understanding users' capabilities and limitations can also be difficult. CCISs are comparatively new, and designers do not have the general understanding of the associated human functions and tasks that the designers of more established systems such as aircraft and armoured vehicles have. Compared with other military systems, CCISs involve many users having a wide range of skills and experience. The experts in computer science and engineering who develop CCISs may not appreciate the differences between themselves and real system users. This can range from 'atomic level' differences in formatting data such as dates and times to user capabilities such as typing and map reading and job-related issues such as the responsibility for authorizing messages.

In addition, although guidelines for the details of the human-computer interface have been developed (Defense Information Systems Agency, 1992, for example) exhaustive, generic, guidelines for the design of CCISs cannot be developed independently from the operators' tasks (Behavioural Team, 1991; NATO AC/243 (Panel-8), 1989). Thus, software development may evolve beyond the concept definition phase before user requirements are sufficiently understood to develop an effective user-computer interface (Overmyer, 1990).

The difficulties outlined above hinder the specification of software of the complexity required for CCISs. As a result, risk is incurred in the selection of existing software packages, or Commercial Off-the-Shelf (COTS) systems for the Canadian Forces (CF) and the development of new systems is hindered.

These issues, and the need to provide advice on the management of the human engineering process were discussed during a workshop on 'The application of human factors engineering in the development of command and control information systems for the Canadian Forces' (Beevis, Essens & Mack, 1993). One conclusion of the workshop was that a generic human engineering programme plan (HEPP) is required which provides the structure to support

[1] also called human engineering - HE

PMO personnel in the specification of HFE and the management of CCIS development and acquisition.

This report addresses the integration of HFE with the development of CCISs. The user-centred development process is presented. A draft of a generic project plan for the application of HFE in CCIS is provided.

THE BUSINESS CASE FOR HFE IN CCIS

From the foregoing material it can be seen that HFE might make a major contribution to ensuring the operability and usability of new systems [2]. Although relevant data are scarce, the application of human factors and HSI can result either in improvements to system performance (or system effectiveness) or in cost savings (Beevis & Slade, 1970). Thus a business case can be developed for taking a user-centred approach to systems acquisition. The business case for the application of human factors in IT systems includes its effects on sales (Chapanis, 1991a), which is not an issue in CCIS. Business cases are usually based on three categories:

- Costs saved
- Costs avoided
- New opportunities.

For IT systems, ‘costs saved’ are often realized through reduced personnel costs. A typical human resources investment model for military systems (Booher & Rouse, 1990) shows several areas where human resources costs may be saved. These include: overall numbers required; rejection rates through selection and training; and job performance. The aim of HSI is to minimize the life-cycle costs of a system through control and tradeoffs between numbers of personnel, skills required, training required, system safety considerations and human factors engineering. The goal of HFE is to match a system to the capabilities and limitations of the anticipated operators, and maintainers, and to ensure that system personnel do function effectively.

‘Cost avoidance’ can be achieved by not putting into the system features that will not be used, or by avoiding cost overruns. Many IT system cost overruns are associated with requests for changes by users, overlooked operator tasks, user’s lack of understanding of their own requirements, and insufficient user-developer communication and understanding (Nielsen, 1993). Cost avoidance is also equivalent to a Quality Assurance approach: problems in operating the system, and the need for their rectification, are avoided. For example, the thrust of Artillery Regimental Data System/Advanced Development Model is to avoid problems with the current manual system, particularly the ‘costs’ of delays and errors. As another example, many new military systems have resulted in ‘skill creep’ where successive systems have required higher levels of skill, experience and/or training than predecessor systems. The application of an integrated HSI and HFE effort can contribute to avoiding such costs in new systems.

For a military application, 'new opportunities' can be realized by insuring that the system is more flexible. This requires attention to the human roles, functions and tasks to ensure that they can behave in a flexible way, rather than being constrained by the system design. In some cases, system availability may be increased. For example, day/night, all-weather

---

[2] Usability has been defined as the set of attributes that bear on the effort required to use (learn, understand and operate) software and on the individual assessment of such use by a stated or implied set of users (APEO, 1993).

operation CCIS operation may be facilitated, or downtime, diagnosis and repair times reduced, or it may be possible for to operate for longer periods without user fatigue affecting the system.

The gains in savings, avoided costs and system flexibility can be evaluated against the costs of the HFE effort. Direct HFE costs for US army systems were estimated at between 3 and 5% of project design costs in the 1960s; recently the costs for HSI activities, which are wider in scope than HFE, were estimated at a similar level, with the highest value of 8% (Booher & Rouse, 1990). In the development of commercial IT systems, a median value of 6% of budget relative to total has been found in a survey of 31 development projects (Nielsen, 1993). The same source reports increases in productivity of 12%, and pay-backs of the investment in HFE ranging from 536% in one year to 200% in the first day of operation.

THE SYSTEM DEVELOPMENT PROCESS

DND acquisition projects are governed by the Defence Programme Management System (DPMS), as outlined in Figure 1. Given the importance of establishing the user's requirements for CCIS, HSI analysis should start in the Project Planning stage of a project. Requirements for system operability, availability and maintainability defined at that stage will determine HSI requirements such as manning levels, skill levels and training requirements.

The System Specification (SS) must include HSI and HFE requirements in more detail, especially for off-the-shelf acquisitions. (MIL-STD-1521B 'Technical reviews and audits for systems, equipments, and computer software' does not address the need to include HSI and HFE requirements into the SS, although is does include 'Human Factors Analysis,' 'Life Cycle Cost Analysis,' and 'Manpower Requirements/Personnel Analysis' in the System Requirements Review (SRR)).

A major part of the development of CCIS involves software. Typically, software is developed during the Implementation phase of a project (CFP A-LP-005-000/AG-006, DND, 1990).

Software Engineering And Human Factors Engineering

While software engineers recognize the importance of HFE, the time and budget constraints of a development effort often force HFE issues to a lower priority in the software engineering process. This observation is particularly true for project teams that lack HFE expertise or experience. Much of the documentation governing the development of systems and/or software does not emphasize HSI or HFE. For example, MIL-STD-881A 'Work breakdown structures for defense military items' does not identify HFE or HSI effort as a work item; instead 'human engineering' is treated as a 'speciality engineering' activity within systems engineering. Recent observation of the ARDS/ADM project showed that even with PMO encouragement, the integration of HFE with other systems engineering activities is far from assured.

HFE specialists can help raise the priority of HFE by suggesting methods of including HFE techniques into existing software engineering structures. This section explores how HFE might be integrated into several relevant software engineering methodologies. The techniques discussed below are all in use in Canada or other NATO countries. The ideas presented here are examples only; significant work, beyond the scope of this report, would be required to fully integrate HFE with the software engineering effort.

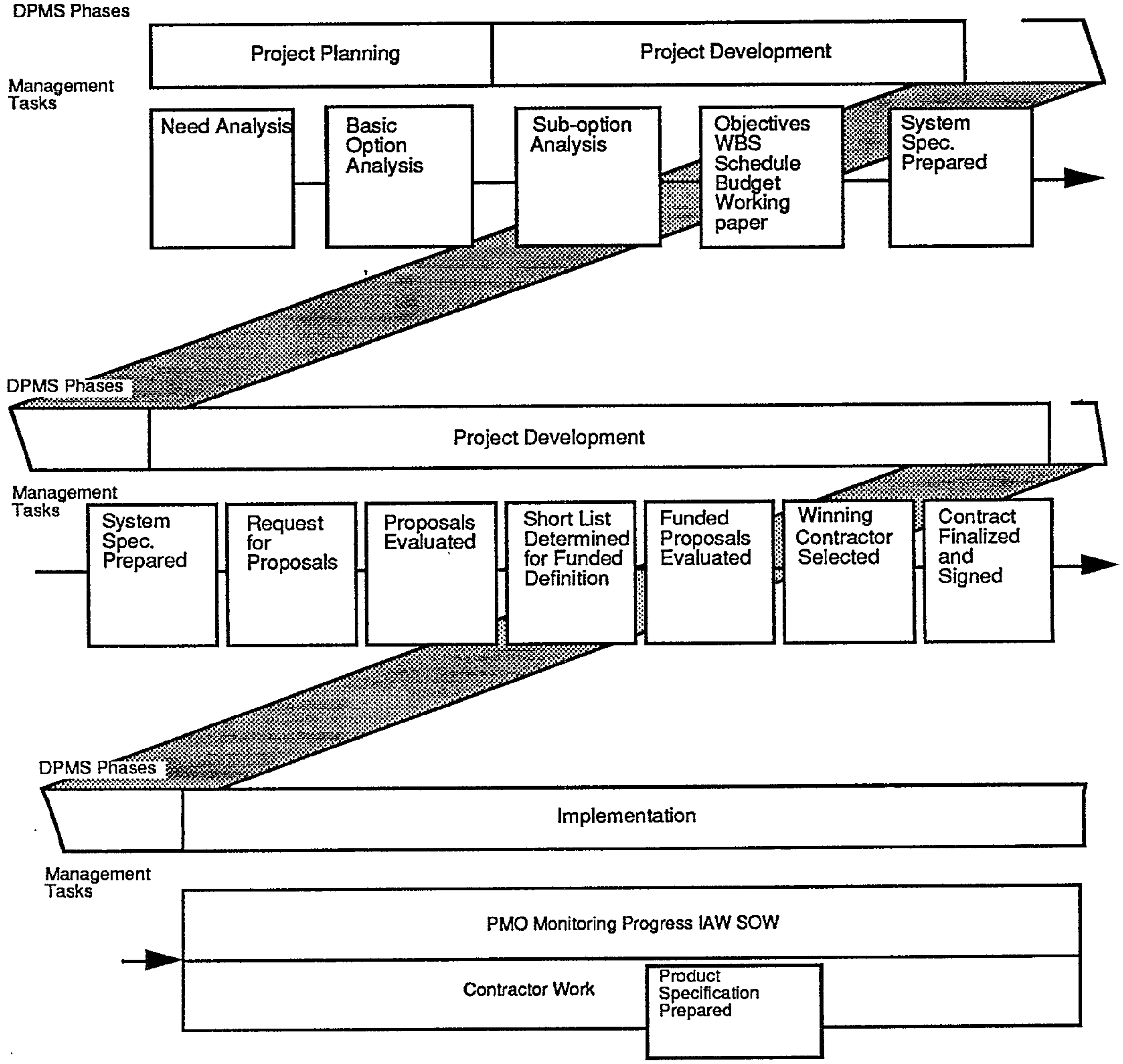


Figure 1: Defence Programme Management System phases and associated management tasks

1. DND Approach to software development

The overall approach to system development is guided by the DND Project Manager's Handbook (A-LP-005-000/AG-001 to 007). Sections of that handbook deal with project management, systems engineering, and logistics support. Chapter 35 deals with Weapon System Software Management. The material relates the Canadian DPMS and the Life Cycle Management System phases to US DOD-STD-2167A on software development. Advice is given on the avoidance of problems with software development. The management of software development during Project Development, Project Definition and Project

Implementation, and the In-Service Stage is reviewed, and work items and products described. Six basic software development activities are identified.

Chapter 35 does not mention HFE as a software development activity (HFE is dealt with as an Annex to Chapter 30 - System Engineering). Six typical problems that occur with software development are listed, the first of which is "original requirements that are incomplete and/or invalidated." The material classifies software errors into three categories:

- requirement errors
- design errors,
- coding errors.

It is recommended that the "RFP should be given special attention to ensure that the 'essential ingredients' are defined to ensure visibility and control by the material developed for the development effort." It is also recommended that the contractor submit plans for matters such as software development, configuration management, design review, quality assurance, and any simulation and test facilities with the original proposal, rather than some months into the contract. This parallels DND experience with the documentation of the human factors programme plan (HEPP). Experience shows that it is preferable to have the HEPP as part of the proposal, rather than have it negotiated several months after contract award when commitments have been made to other contract work items.

2. US DOD-STD 2167A Defense Systems Software Development

This standard "establishes uniform requirements for software development that are applicable throughout the system life cycle [the acquisition, development, or support of software systems] .... [which] provide the basis for Government insight into a contractor's software development, testing, and evaluation efforts. ... It is not intended to specify or to discourage the use of any particular software development method. The standard, should be used in conjunction with MIL-STD-499, Engineering Management." DOD-STD-2167A identifies the project phases, deliverables and criteria for evaluating them, progress reviews, and records which must be kept by the contractor. The project phases (Figure 2) can be related the to six basic software development cycle activities identified in the Chapter 35 of the DND Project Manager's Handbook.

DOD-STD-2167A is based on a phased development process:

a. System Requirements Analysis/Design
b. Software Requirements Analysis
c. Preliminary Design
d. Detailed Design
e. Coding and CSU Testing
f. CSC Integration and Testing
g. CSCI Testing
h. System Integration and Testing

As shown in Figure 2, the standard relates the various design reviews and the deliverables associated with those activities to the development phases. It does not cover the initial stages of the DPMS, or later stages of life-cycle management (ADGA, 1994).

Deliverables are specified by 18 Data Item Descriptions (DIDs) covering plans, design documentation, tests, and manuals (Appendix A). The standard also identifies the types of criteria for evaluation of deliverables. The requirements for documentation of the software development in terms of its decomposition, traceability to design requirements, design standards used, performance requirements, test requirements, configuration management, etc. are identified.

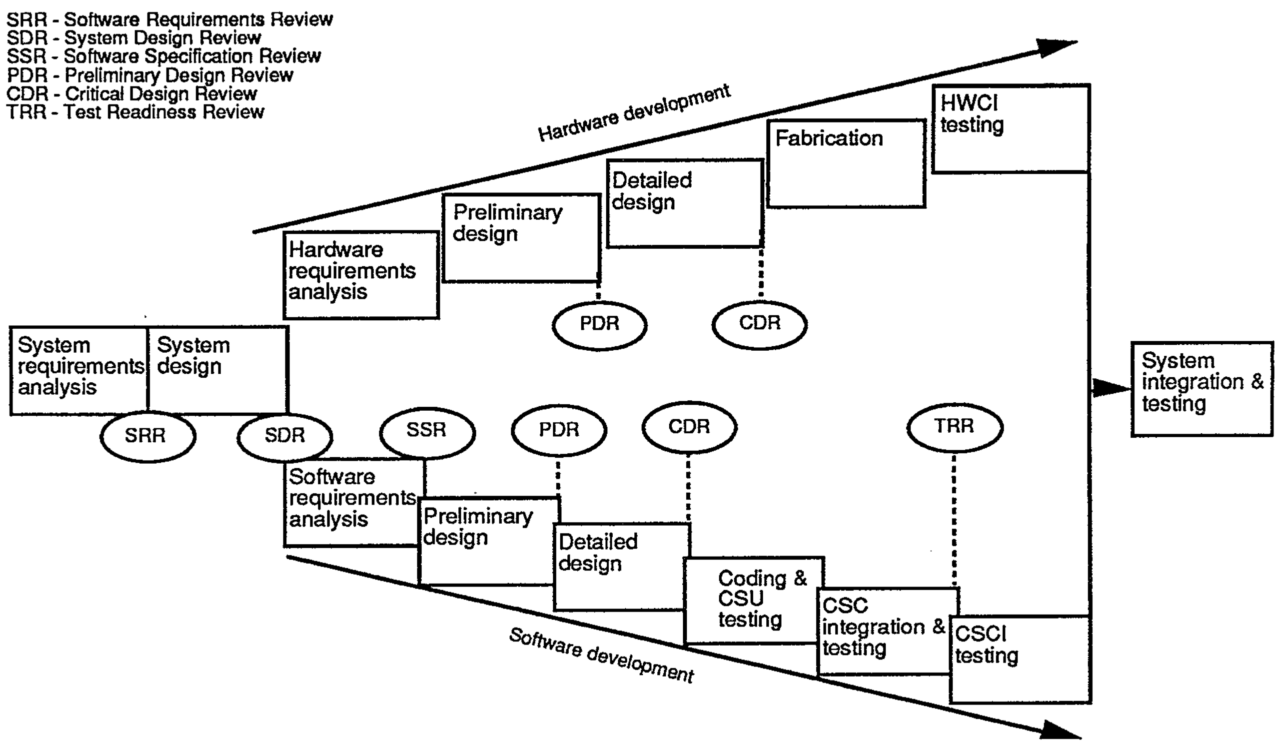


Figure 2: System development reviews and audits suggested by DOD-STD-2167A

Standard 2167A is cross-referenced to:

DOD-STD-480	Configuration Control - Engineering Changes, Deviations, and waivers
MIL-STD-481	Configuration Control - Engineering Changes, Deviations, and waivers (short form)
MIL-STD-490	Specification Practices
MIL-STD-499	Engineering Management
MIL-STD-1521	Technical Reviews and Audits for Systems, Equipments, and Computer Software

The standard does not address HFE directly. However, MIL-STD-490, MIL-STD-499 and MIL-STD-1521B do address HFE, and an HFE management plan can be produced which is compatible with DOD-STD-2167A, as follows:

- MIL-STD-490 includes standard paragraphs for the inclusion of Human Engineering and Personnel and Training requirements in system specifications
- MIL-STD-499 requires that Engineering Speciality Integration ensure "the timely and appropriate intermeshing of engineering efforts and disciplines such as reliability, maintainability, logistics engineering, human factors, safety, value engineering, standardization, transportability, etc. to insure their influence on system design."
- MIL-STD-1521B covers seven project reviews and three audits. The project reviews cover Human Factors Analysis as a topic, from the System Requirements Review (SRR) onwards. The review also covers other aspects of HSI, including logistics support analysis, and Manpower Requirements/Personnel Analysis.

An iterative approach to system development could be accommodated within the 2167A framework provided that iteration is limited to the specific project stages. Metersky (1993) proposes a modification to the 2167A pattern of development which expands the Software Requirements Analysis and Preliminary Design phases to include the following steps:

- Specify mission requirements or operational problems
- Identify operational user community
- Perform operational user requirements analysis
- Perform functional requirements analysis
- Develop preliminary system architecture
- Build a prototype
- Test in lab
- Test in operational environment: solicit refinements and extensions
- Implement revisions/enhancements
- Reiterate incremental developments

3. METHOD/1™

METHOD/1 is the registered trademark of a toolset produced by Andersen Consulting for developing software systems. The tools have been selected by DND as part of a proposed standard System Development Methodology (SDM):

> "This directive identifies the use of the METHOD/1, the Systems Development Methodology as mandatory for any project developing or acquiring a multi-user information system that includes an application software component and that is not exclusively a process control system. "(DIS Arch, 1993)

METHOD/1 is supported by CASE software. The software includes much of the documentation, estimating tools, and project management tools. DND is supporting the distribution and use of the software and techniques.

METHOD/1 is a functional decomposition of the software life cycle. At the top level are phases, including: Information Planning, Custom Systems, Packaged Systems (i.e., Commercial Off-the-Shelf or COTS), Iterative Systems, and Support. Some phases are optional and some are exclusive of others. For example, a system is (typically) primarily either a Custom system or a Packaged system. Each phase is decomposed into segments and segments are further broken down into tasks; within a task can be found work steps.

Two aspects of METHOD/1 make it attractive for the software life cycle. First, there is extensive support for management of software projects. Systems Development Management activities occur in parallel with all phases of METHOD/1. Project managers are provided with guidance constructing business cases, selecting project teams, estimating system costs and time lines, etc. A project manager need not be a software engineer to work effectively with METHOD/1. Second, METHOD/1 provides extensive examples of management reports, deliverables, and checklists called 'object samples'. While the samples are not intended to be a comprehensive set of system definition, description, and documentation - they have in practice been directly invoked by project managers.

Human Engineering activities could be integrated into METHOD/1 using the functional decomposition approach. For example, Beevis et al. (1993, Figure 93) present a list of work items in the human factors engineering process which parallel METHOD/1 segments. The same report also contains a list of deliverables (ibid., Figure 94) which could be the basis for METHOD/1 object samples and linked to METHOD/1 segments. While significant work would likely be involved, the result would offer project managers a well defined and easily managed way to integrate human engineering techniques into the software life cycle.

4. Hatley-Pirbhai

Hatley-Pirbhai (H-P) is a published method for real time system specification (Hatley and Pirbhai, 1988). The method was developed to address a deficiency in structured analysis techniques that was identified during development of a large avionics system. The Hatley-Pirbhai method was selected by the ARDS/ADM contractor as the structured analysis and design method for the project. The H-P method covers only the early stages of the software engineering process; it does not include system implementation and testing. Therefore, a complete integration of HFE methods cannot be built around H-P. However, with that reservation, the H-P system is discussed below.

Hatley-Pirbhai recognizes that system development is an iterative process, an important concept for user-centred design and the successful integration of HFE. An overlapping cycle of requirements, design, implementation and test is noted in the reference. Requirements are addressed by the construction of Data Flow Diagrams (DFDs) and Control Flow Diagrams (CFDs). The requirements are then transformed into an architecture model by considering design constraints such as performance, expansion capability, safety and reliability.

Consideration of the human in the system is included in requirements model construction. Users are categorized as owners, operators, maintainers, designers and builders. The role of each is described in general terms. Users are also identified as the major source of system requirements, in the form of statements of needs. Some of the difficulties involved in collecting and defining these statements are discussed briefly, but little guidance is provided.

It is difficult to imagine a complete integration of HFE into Hatley-Pirbhai. In book form, H-P provides great detail concerning the construction of requirements and architecture models using structured techniques. Consideration of HFE at various stages of model construction would have to be treated separately, with references to the H-P process. Interpretation and perhaps modification of the H-P stages would be required. The result would likely be a 'take-it or leave-it' compendium with weak links. Successful use of HFE with the H-P system would likely require an HFE expert on the design team.

5. Object-Oriented Software Engineering

Object-Oriented software engineering is quickly growing in use and popularity. DND contractors are studying and using the techniques. The ARDS/ADM contractor identified the need to relate Object Oriented Programming (OOP) and HFE (Beevis et al., 1993). The United States Air Force's Armstrong Laboratory has issued a standard for Object-Oriented system design, recognizing the growing popularity of the method (Mayer, Keen & Wells, 1992). OOP can be characterized by three attributes (Berard, 1993):

- Information is localized around objects, where an object is a thing or a pattern of things
- Objects are complete entities, containing as complete a description as possible; and
- Objects are independent of each other, but can be arranged in a hierarchical manner.

This broad definition of object includes things like Organization, Operator, and Event. A group of objects with common attributes is defined as an object class. Depending on the model, any one of the above objects could be a class. For example, Organization might be a class containing Service-Organization, Manufacturing-Organization, and Government-Organization. Members of an object class inherit attributes of the class-object. The Organization class might have attributes such as number-of-members, name, and annual-budget. Each of the more specific types of organization inherits these attributes.

One Object-Oriented development system is Smalltalk/V™ by Digitalk™. The introduction to the Smalltalk/V Mac documentation contains the following (Digitalk, 1991):

> "Smalltalk grew from a few powerful ideas.
> - The most important component in a computing system is the individual human user.
> - Programming should be a natural extension of thinking.
> - Programming should be a dynamic, evolutionary process consistent with the model of human learning activity."

This quote could easily have been taken from a text on human-computer interaction. OOP concepts align closely with those of human engineering.

The concepts of OOP were developed in the 1960s and 1970s. More recently object-oriented approaches to the analysis and design stages of the software life cycle have emerged (Coad and Yourdon, 1990). Object-Oriented Analysis (OOA - also called Object-Oriented Requirements Analysis - or OORA) and Object-Oriented Design (OOD) have evolved from the need to blend changing programming preferences (i.e., OOP) with the traditional software life-cycle.

The object-oriented approach to software systems holds promise for the integration of Human Engineering concepts. OOA includes the identification of major objects in a system - an excellent opportunity to include the human in the system concept. Characteristics of major objects are identified and included in object definition. Some basic examples of human attributes are name, age, and address. However, human attributes could include, for example, cognitive work style, personality type and 'handed-ness' - items less frequently associated with software design.

A Human Engineering analysis of a system will often include a task analysis. One method, Task Analysis for Knowledge Descriptions (TAKD, Johnson, Diaper & Long, 1984) refers to 'specific objects', which are defined as:"... all objects that are relevant to the performance of a task, or set of tasks. The definition of an object is somewhat problematical in that a specific object may be a part of a larger object" (Diaper, 1989). This example shows that object-oriented techniques allow for system definition in similar terms as those used in task analysis. A task analysis system called 'Analysis for Task Object Modeling' (ATOM) has been developed to aid users of traditional structured design methods in considering user interface design (Walsh, 1989). ATOM descriptions are created by "... analyzing principal objects of the system, and ... identifying the major actions associated with each object." These activities strongly parallel object-oriented concepts.

One of the three attributes of OOP noted above is the localization of information around objects. Included in this concept are methods, or actions which can affect an object. The Human Engineering process of functional decomposition usually results in a list of actions by a particular operator. In OOA, each operator may be represented by an object and tasks assigned to that operator may be represented by that object's methods.

In summary, an object-oriented approach to software systems is highly compatible with human engineering activities. The human can be viewed as part of the system, integrating human engineering with system engineering. Human engineering information such as cognitive work style and tasks performed by each operator can be encapsulated in an object-oriented model.

Conclusions

Overall, the material reviewed does not place a strong emphasis on HFE or user requirements or their integration with software development activities. The review shows, however, that HFE can be included into various approaches to software development provided that such activities are planned for.

THE USER-CENTRED DEVELOPMENT PROCESS

The experts who attended the workshop on 'The application of human factors engineering in the development of command and control information systems for the Canadian Forces' (Beevis et al., 1993) agreed that adopting a user-centred approach to information system development provides the best way to ensure proper consideration of human factors issues.

The 'user-centred' approach has not been clearly defined in the way that 'human factors' and 'operability' have (DND-ENG. STD-3, 1969). A user-centred approach can be considered as focussed on human system integration. Such an approach would provide the answers to the questions posed by the US Army's HSI (MANPRINT) programme :

"Can this soldier
with this training
perform these tasks
to these standards
under these conditions?"
US Department of the Army, 1990).

Approaches to user-centred development have been called 'multi-disciplinary information systems engineering' (Andriole, 1990), 'user engineering methodology' (McLaughlin, 1987), 'user-centred system design' Norman & Draper, 1986), and 'usability engineering' (Whiteside, Bennett & Holtzblatt, 1988; Nielsen, 1993).

Andriole's (1990) approach supports the principles of top-down design, and hierarchical decomposition, synthesis, iteration and assessment. It calls for extensive use of prototyping and stresses the importance of identifying user requirements before software requirements are specified.

McLaughlin's (1987) approach emphasizes iterative development through user evaluation of a prototype. His 'user engineering methodology' has been combined with traditional system engineering techniques to develop complex man-machine systems. The approach is intended to gather data about the potential system users and incorporate those data into the design process as early as possible. The methodology emphasizes, defines, validates, and maintains the user's view of the system being developed.

Thus user-centred approaches emphasize problem definition and requirements development as well as iterative development and testing (Williges, Williges & Elkerton, 1987). An outline of the major activities in such a programme is shown in Table 1.

Key features of these approaches include:

- a 'user analysis' to derive a model of the user group
- the development of specifications which include 'usability' requirements
- evolution of the design through iteration
- testing the design through prototyping using 'usability' criteria

The current report is written to advocate an iterative approach to the user-centred development process and to summarize relevant information draw from several sources. The information on a user-centred approach includes:

- user involvement and establishing user profiles
- prototyping and iterative development in concert with analysis
- testing against usability criteria

Table 1: Work items for the user-centred approach to systems

1. ITERATIVE PROBLEM DEFINITION
   - identification of stakeholders and their relationships
   - identification of problems & goals
   - exploration of goals - what can be achieved with certainty
- what it is hoped can be achieved
- what it is desirable to achieve
   - identification of organization implications
   - development of a user participation plan
2. ITERATIVE REQUIREMENTS DEVELOPMENT
   - user analysis
   - system, organizational & training analysis
   - specification of performance goals & criteria
   - concept development, allocation of functions, concept exploration & demonstration
3. ITERATIVE DESIGN/PROTOTYPE & TEST
   - detailed task analysis
   - detailed performance goals
   - system, interface & training system demonstration & design
   - evaluation of a functional prototype (at SDR, PDR & CDR)
4. TRANSITION OF PROTOTYPE TO PRODUCTION
5. FIELD TRIAL

User Involvement and Establishing User Profiles

The specification for HFE activities, US MIL-H-46855B para 3.2.3.2 of Test and Evaluation requires that "Use of military personnel from the intended user population is preferred where feasible." However, user-centred iterative development involves more than just employing users as subjects in acceptance tests. A range of user representatives is required throughout the project life-cycle. This includes the user groups which are sponsoring the development, the end user agencies, the users' representatives in the PMO, and any user assigned to advise the contractor's team. Input can be provided on an occasional basis by review teams and focus groups, or on a continuing basis by users in the PMO team.

User involvement includes the following:

- identifying, refining and validating requirements
- defining user capabilities and expectations
- prioritizing design objectives
- monitoring, advising and overseeing design decisions
- deciding on design tradeoffs
- evaluating prototypes or models
- establishing validation and acceptance criteria

There are several means of identifying, and refining user requirements for a new system. These include surveys or questionnaires, interviews, and experts (Rouse, 1991). Focus groups of experts or system users can provide valuable insight into the requirements for new systems (Jordan, 1994). Those requirements can be documented as statements of desirable characteristics, for example, the need to avoid scrolling through many pages of information (ibid.). User requirements can also be expressed as scenarios and mission analyses and as system functions (see NATO AC/243 Panel-8/RSG.14, 1992). Narrative mission descriptions and functional analyses proved to be extremely useful in identifying the users requirements in the ARDS/ADM project (Essens, Beevis & Mack, 1994).

Several approaches can be taken to defining user capabilities. McLaughlin (1987) advocates 'user analysis' (conducted prior to task analysis), by which a representative profile of the user group is formed from results of interviews, from observations, and from cognitive, work style and personality measures. User analysis for CCIS is a recent development, however, and it will be some time before methods appropriate for non-specialist designers are established. What is important is to be aware that designers implicitly assume a user profile when designing systems, and that this profile may not be appropriate and should be formulated more explicitly.

Lacking a robust approach to user profiling, current practice emphasizes user input to iterative development and test. This approach can be structured to reflect increasing design definition throughout the project (Engel & Townsend, 1989). Often, cost constraints limit the user representatives in the PMO team to only one or two people. This may introduce biases which must be balanced by the opinions of other users during concept and design reviews (Essens et al., 1994). Early activities could involve only the expert users, who give feedback for testing and verifying concepts and ideas. Later, as the design matures, prototyping, tests, and field trial activities should involve a broader range of users who represent those who will finally operate the system.

Prototyping and Iterative Development

A prototype is "the first or primary type of anything; a pattern, model, standard, exemplar, archetype" (OED, 1933). In software engineering, a prototype is often a tentative or intermediate tangible representation of a (partial) solution to a problem. Its purpose is testing the validity of the assumptions on which the representation is based. Because it is tangible, users are better able to criticize the chosen solutions. Prototyping allows implementation more rapidly and more safely in projects with poorly understood requirements or goals. Prototyping reduces the risk (costs) of investing in an ineffective solution.

In the human factors literature, prototyping is often equated with creating the human-computer interface (Nickerson & Pew, 1990). The interface is where the functionality of the system becomes concrete for the user. In system development, however, specification of the interface is usually done after the specification of the requirements. It is a further detailing out of how the user-computer combination will do a task. The prototype effectively communicates the 'look and feel' of the real system and appears to the user as if it actually works. To use prototyping early on in the development of concepts requires a representation that can capture ideas and system concepts but stays away from the details of an interface.

1 Why is prototyping so important to the user-centred development process?

Prototyping is the cornerstone of a user-centred approach to software engineering. A prototype is the means by which users and system designers reach a common understanding of system requirements. Prototyping encourages design iteration (Beevis & St Denis, 1992). Rapid, evolutionary prototypes provide users with the opportunity to set design priorities and accept responsibility for the success of their system. The use of prototypes helps system designers reduce uncertainty and maintain quality. Effective prototyping speeds the system development process and builds user confidence in the design team.

2 When to prototype

Prototyping should occur throughout the design and testing of a CCIS. In the definition stage of a project, story boards may be used to help stakeholders appreciate what can be expected of an automated system. During conceptual design and analysis, prototypes establish and confirm requirements[3]. Early prototypes facilitate early testing and the early definition of measures of system performance. During design, a prototype can validate a previous analysis and serve to obtain user input. At the end of the design phase, a deliverable prototype can serve as the design definition. In system testing, fully functional prototypes can be examined under controlled conditions to confirm system effectiveness. Every prototype should have a clearly established purpose and set of evaluation criteria; these may differ depending on the stage of development.

Prototyping is a well established technique in custom system design. More recently, 'off-the-shelf' software is finding its way into CCIS. Combinations of commercial and custom software provide less expensive, more quickly fielded systems. In these cases, a high-level prototype can be used for software selection and testing integration concepts. Since hybrid systems provide less configuration control, the use of prototyping to identify any limits on meeting requirements is important. The description of one recent DND CCIS project (Helleur, Richardson & Roy, 1994) concludes that rapid prototyping of a hybrid system produced an initial system in less than six months.

3 Prototyping has its problems

Prototyping is necessary for a successful user-centred approach to system design, but it must be approached with caution and it does not replace the requirements analysis process.

[3] McLaughlin (1987) has argued that "new procurement procedures are needed in order to insure that these activities are conducted early. Formal documentation deliverables in contracts must initially yield to the delivery of prototypes, and the analysis surrounding their development and trial use." Such prototypes could be accepted as 'samples and models' as part of a proposal or specification, as outlined in the CF instructions for specification preparation (DND, 1979).

Prototyping does not have universal acceptance among software engineers. Not all applications of prototyping have been successful. There are reports of a Canadian Forces project which was "prototyped to death." Some problems that have been identified are:

- prototyping requires significant user involvement, which has to be organized and forms another management factor
- there is no database of prototype successes, making comparisons difficult
- prototyping is not a design short cut, but requires ITERATIONS, which may slow the early stages of system analysis and design
- prototyping evokes wedding to initial ideas
- prototyping is less suitable for very large projects, process-oriented projects and when test time is limited
- prototyping fails where users insist on doing the work the same way as before
- prototyping fails when customized to support several different users' views
- prototyping is ineffective when sub-projects are poorly coordinated, there are poor development standards, or inexperienced staff.
- prototyping efforts may not be subject to formal test or evaluation (Beevis & St Denis, 1992).

Overmyer (1990) has argued that negative reports of using prototypes, in particular concerning the time spent on them, are typically due to poor selection of the methodologies and tools.

4 Analysis and prototyping

Prototyping has a trial and error characteristic. To be efficient and to avoid too many obvious errors and backtracking, the problem has first to be analyzed. Lack of sufficient analysis can inhibit the development of a successful design (Melkus & Torres, 1988). Experience with the ARDS/ADM project has confirmed the value of analyses of system missions (using narrative mission descriptions), and system functions, as a means of defining operator functions and tasks (Essens et al., 1994). Previous studies have shown that task analysis can be used effectively in the development of a prototype (Beevis & St Denis, 1992).

Lack of sufficient analysis can also hinder the evaluation of a prototype. This occurred in the DCIEM development of the concept of the SHINMACS standard operating console for ship's machinery. The concept was developed based on a top-level analysis of operator functions and tasks (Gorrell, 1979), and developed using a personal computer to prototype the system screen designs and interactive protocols. The design of the prototype was used to establish the specification for the Advanced Development Model (ADM) of the console (Gorrell, 1980, 1981). However, the operator functions and tasks were not analysed further, so the performance requirements for the ADM were not established and could not be used for the ADM evaluation.

However, although systems development texts emphasize the importance of analysis, an analysis does not always provide:

- any answer
- a useful answer
- a correct answer!

A prototype can help identify where analysis has fallen short by forcing designers to make decisions that may not have been given their due regard in the analysis activities.

Thus, the right balance must be achieved between seeking more information about the problem and putting effort into representing what is known with a chance of failure. This is not always easy, as stated by Seaton and Stewart, (1992): "Putting it another way, analysis-driven designs have tended to be unusable, whereas user-driven designs have been unbuildable." In a procedure that can be characterized as 'build a little, test a little', small steps are taken to simultaneously find out whether the solution addresses the goals, and develop a further specification of the goals.

5 Conclusions about prototyping

In summary, prototyping is key to the success of a user-centred approach to system design. Prototypes provide users the means to take responsibility for their system and give designers a tool for reducing uncertainty and ensuring a quality design. To be successful, prototyping should be rapid and evolutionary in nature and occur in all phases of a project; unfortunately this is not always the case. Prototyping, when poorly applied, will fail and will delay a project. Analysis and prototyping are integral and complementary techniques in system design. A successful user-centred approach will use the strategy, 'build a little, test a little.'

Testing Against Usability Criteria

Usability in an information system is a multi-dimensional concept that includes elements such as (ANSI/AIAA, 1992):

- level of detail of information
- reliability of the system
- accuracy of the information
- ability to alert the user to change
- built-in diagnostic procedures and graceful degradation
- non-intrusiveness into the task
- operator acceptance of the system
- simplicity of information
- timeliness of information
- quality (i.e. subjectivity) of information
- flexibility of the system.

The evaluation of usability is not simple, and includes both objective measures of performance and subjective measures of users' response to the system (Chapanis, 1991b). Evaluation of a command and control system includes a wide range of objective and subjective measures (Engel & Townsend, 1991; Human*Systems,* 1993; Sweet, Metersky & Sovereign, 1986).
Successful information systems must include trials by a sample of the user community. In CCIS, field trials of the system are critical because field conditions are often difficult to simulate for prototype testing; field trials may provide the only opportunity for access to portions of the user community.

In a user-centred approach field trials occur under the direction of a test plan which includes elements noted above. Relative levels of detail in the testing are prioritized and determined by stakeholders, including users. Results of testing can be compared to pre-determined acceptance criteria, or used to establish system operating constraints [4]. Field tests lead to specifications for future improvement and final modifications to the design.

---

[4] The distinction between acceptance criteria and establishing system operating constraints is determined by whether there is an existing system and associated performance data. Separate field trials may be necessary early in system design to determine performance data for an existing system.

User-Centred Approach and COTS Acquisitions

Much of the foregoing description of a user-centred developmental approach also applies to projects where COTS software and equipment are to be used. The unqualified adoption of COTS would assume that CF users have the same capabilities, training, and experience as those for which the COTS system was designed and that they use the same doctrine and procedures. Clearly this is seldom the case. The basic HSI questions must still be answered to ensure that the system matches the users. This means that the users and their capabilities and skills must be clearly defined to bidders and that the evaluation of any proposed COTS must take a user-centred approach. As noted in the description of the system development process, the system specification must include HSI and HFE requirements.

The US Government has developed a set of questions to determine the extent to which human factors were considered in the system acquisition process (US GAO, 1981). Those questions emphasize personnel and training but also include HFE; they might be used to audit HSI issues for COTS acquisitions. For example, auditors are required to determine whether, during the full scale engineering development phase of a project, "man-machine tradeoff criteria were used in the development of operation and maintenance ... control/display/software design concepts ... [and to] ... assess the extent to which developmental tests demonstrated (1) system conformance with human factors engineering design criteria, (2) the adequacy of the training approach, (3) acceptability of system-imposed operator workload, and (4) system safety."

The US Army has developed a much more detailed approach to HSI for non-developmental item acquisition (US ARI, 1988). Although directed at the US Army's MANPRINT programme, the overall process may provide the basis for COTS acquisitions for DND. The approach has five phases (Marton & Toomer, 1989):

- Phase 1 - Identification of mission requirements and constraints
- Phase 2 - Identification and description of required item characteristics and selection criteria
- Phase 3 - Search or survey to identify potential candidates and collect information related to required characteristics
- Phase 4 - Assessment and comparison of candidates against criteria, and selection of system
- Phase 5 - Test and development (in exceptional cases) to improve operational, survivability, cost, scheduling or other features

For conventional systems, identification and description of the HFE features can be achieved through the completion by bidders of the Human Engineering Design Approach Document - Operator (HEDAD-O) and the Human Engineering Design Approach Document - Maintainer (HEDAD-M). Those deliverables are specified by US DoD DIDs, respectively DI-HFAC-80746 and DI-HFACE-80747 (US DoD, 1987). The DIDs require the bidder to describe the layout, detail design and arrangement of crew station equipment and operator and maintainer tasks. Although comprehensive HEDADs are extremely useful for describing systems for HFE evaluation, the dynamic aspects of CCIS require evaluations to include prototypes, dynamic mockups, or actual system operation. A draft DID covering rapid prototyping activities has been prepared, but has not yet been adopted as a standard (Steiner & Ims, 1991).

Projects which use COTS do not necessarily acquire a complete system. It may be that there are opportunities to take advantage of available COTS components such as a geographical information system, a relational data base, or a commercial word processor. In those cases developmental effort is still required and the overall approach to development outlined in this report is relevant.

DRAFT GENERIC HEPP

Introduction

The basis of any planning for HFE activities is the project Statement of Requirement (SOR) and Request for Proposals (RFP). If the PMO does not make clear the importance of user requirements in the SOR, and of HFE in the RFP, then the contractor cannot be expected to place any importance on those aspects in their work (NATO AC/243 Panel-8, 1984). Whether the systems have been designed already or have yet to be developed, the HFE activities should be the subject of a project plan, usually referred to as the Human Engineering Programme Plan (HEPP).

The HEPP defines the requirements for applying human engineering to a project, including the work to be accomplished in conducting a human engineering effort integrated with the total system engineering and development effort. The HEPP provides the basis for including HFE during proposal preparation, system analysis, task analysis, system design (including computer software design), equipment and facilities design, testing, and documentation and reporting.

Experience in the application of HFE in a number of DND projects suggests that the scope of the HFE activities is strongly related to the preparation of a HEPP (Beevis, 1987). Experience with the ARDS/ADM project supports the importance of the HEPP (Essens et al. , 1994). The HEPP should cover the following (Beevis et al., 1993):

- work items: stakeholder identification
requirements development
analysis - scenarios, missions, functions, operator tasks
design and development
interface specification
prototyping
iterative development
test and evaluation

- relationship of HFE activities to other systems development activities (SSS review, etc.)
- schedule
- meetings
- reviews
- deliverables: plans, progress reports and results of studies, tests, trials and evaluations.

The plan must be compatible with the documents shown in Table 2.

Table 2: Documents relevant to HFE in CCIS

REGULATORY

- DND PM Handbook, CFP A-LP-005-000/AG, chapter 35
- US MIL-H-46855B Human Engineering Requirements for Military Systems, Equipment and Facilities
- US MIL-STD-490 - Specification Practices
- US MIL-STD-881A - Work Breakdown Structures for Defense Material Items
- US MIL-STD 1388-2B - Logistic Support Analysis
- US MIL-STD-1521B (USAF) - Technical reviews & audits for systems, equipments and computer software
- US MIL-STD 2167A - Defense System Software Development
- METHOD/1™

GUIDANCE

- NATO AC/243(Panel-8)TR/7 - Analysis techniques for man-machine systems design, Volumes 1 & 2
- NATO AC/243(Panel-8) RSG.19 report - Toward a framework for Cognitive Analysis, Design, and Evaluation
- UK Human factors guidelines for the design of computer-based systems, Volumes 1 - 6, HMSO
- Human factors in command-and-control system procurements, (Copas, Triggs, & Manton, 1985)
- Guidelines for the design and evaluation of operator interfaces for computer based control systems, (Engel & Townsend, 1989)

Work Items

In DND projects, the HEPP is usually based on the DID DI-HFAC-80740 'Human engineering program plan' (US DoD, 1987). The tasks to be included in the plan are specified by US MIL-H-46855B 'Human engineering requirements for military systems, equipment and facilities' (US DoD, 1979). That specification "establishes and defines the requirements for applying human engineering to the development and acquisition of military systems, equipment and facilities" including "the work to be accomplished by the contractor or subcontractor in conducting a human engineering effort integrated with the total system engineering and development effort" as "the basis for including human engineering during proposal preparation, system analysis, task analysis, system design (including computer software design), equipment and facilities design, testing, and documentation and reporting."

The work items in MIL-H-46855B are compatible with the usual, sequential, systems development process (Table 3). The work items start with the analysis of functions and concentrate on the traditional areas of human engineering. As Overmyer (1990) has noted, MIL-H-46855B does not preclude an iterative approach to system development, and provides a starting point for the development of a generic human factors engineering plan for CCIS.

Table 3 : Work items in US MIL-H-46855B

1. ANALYSIS
   - Defining and allocating system functions
   - Information flow and processing analysis
   - Estimates of potential operator/maintainer processing capabilities
   - Allocation of functions
   - Equipment selection
   - Analysis of tasks
   - Preliminary system and subsystem design

2. DESIGN AND DEVELOPMENT
   - Human engineering in equipment detail design
   - Studies, experiments and laboratory tests
   - Equipment detail design drawings
   - Work environment, crew stations and facilities design
   - Human engineering in performance and design specifications
   - Equipment procedure development

3. TEST AND EVALUATION
   - Planning
   - Implementation
   - Failure analysis

Comparison of Table 1 with Table 3 shows that the major differences between the user-centred approach advocated for CCIS and MIL-H-46855B is in the emphasis placed on requirements development and initial analyses. Some of this work must be undertaken by the procuring agency, as discussed below. With those requirements in mind, an initial approach to a generic HEPP for CCIS has been developed from US-MIL-H-46855B, with necessary amplifications and explanation, as set out below.

HEPP based on US MIL-H-46855B

MIL-H-46855B REQUIREMENT	COMMENTS, ADDITIONS OR CHANGES REQUIRED
1.1 Scope - This specification establishes and defines the requirements for applying human engineering to the development and acquisition of military systems, equipment and facilities. These requirements include the work to be accomplished by the contractor or subcontractor in conducting a human engineering effort integrated with the total system engineering and development effort. These requirements are the basis for including human engineering during proposal preparation, system analysis, task analysis, system design (including computer software design), equipment and facilities design, testing, and documentation and reporting.	The work items needed for a user-centred approach cover a wider scope. More emphasis must be placed on requirements definition, including the development of scenarios and mission analyses. Some of this may be the responsibility of the procuring agency rather than the contractor. Thus, the overall HEPP for a CCIS project should include procuring-agency activities, and the PMO and contractor should use the HEPP to define their relative responsibilities.
1.2 Applicability - It is not intended that all the requirements contained herein should be applied to every program or program phase. In accordance with DoD principles, directives and regulations governing the application and tailoring of specifications and standards to achieve cost effective acquisition and life cycle ownership of defense materiel, this specification shall be tailored to specific programs and the milestone phase of the program within the overall life cycle. This tailoring shall be the selected application of methods, tables, sections, individual paragraphs or sentences, or a combination thereof, to be placed on contract in order to impose only the minimum essential needs to preclude unnecessary and unreasonable program costs. Guidance for selection by the procuring activity of this specification for contract use, and, when invoked, the partial and incremental application of the requirements provisions, is contained in the Appendix.	In view of the need for iteration in the development of CCIS, there must be a clear agreement on the number of cycles of iteration to be undertaken "to impose only the minimum essential needs to preclude unnecessary and unreasonable program costs". see Morgan 1989.
2. APPLICABLE DOCUMENTS	Other documents could be referenced, for example: • US Defense Information Systems Agency Human Computer Interface Style Guide, Version 2.0, September 30, 1992 • Guidelines for Designing User Interface Software • NATO AC/243 (Panel-8)TR/7, (1992). Analysis Techniques for Man-machine System Design.

3. REQUIREMENTS

3.1 General Requirements

The scope and nature of the work should include the identification of user requirements for the projected system. This may require the addition of a sub-section on Requirements Definition.

3.1.1 Scope and Nature of Work - Human engineering shall be applied during development and acquisition of military systems, equipment and facilities to achieve the effective integration of personnel into the design of the system. A human engineering effort shall be provided to develop or improve the crew-equipment/software interface and to achieve required effectiveness of human performance during system operation/ maintenance/control and to make economical demands upon personnel resources, skills, training and costs. The human engineering effort shall include, but not necessarily be limited to, active participation in the following three major interrelated areas of system development.

Activities necessary for requirements analysis and definition must be added. These activities should be interrelated with the analysis, design, and test and evaluation activities to support iterative development. Test and evaluation should include story-boarding and prototyping efforts.

3.1.2 Human Engineering Program Planning - Human Engineering Program Planning, in accordance with the requirements of this specification and the equipment specification, shall include the tasks to be performed, human engineering milestones, level of effort, methods to be used, design concepts to be utilized, and the test and evaluation program, in terms of an integrated effort within the total project.

The activities of requirements definition, concept development, allocation of functions, and concept exploration must be integrated with Design, Test & Evaluation activities. The extent of iteration anticipated in the HFE activities should be identified. Such planning should include the preparation of a User Participation Plan, a Rapid Prototyping Plan, and a Plan for Resolving Issues.

3.1.3 Nonduplication - The efforts performed to fulfill the human engineering requirements specified herein shall be coordinated with, but not duplicate efforts performed in accordance with other contractual requirements. Necessary extensions or transformations of the results of other efforts for use in the human engineering program will not be considered duplication. Instances of duplication or conflict shall be brought to the attention of the Contracting Officer.

No changes required.

3.2.1 Analysis - Mission analysis shall be developed from a baseline scenario. Analysis shall include application of human engineering techniques as follows:

This section should refer to the need for iterative Requirements Development, and should cover:
- User Analysis
- System, organizational & training analysis
- Specification of performance goals & criteria.

The ARDS/ADM project has confirmed the value of scenarios (strictly, narrative mission descriptions) prepared and reviewed from the users' perspective (Essens et al., 1994). The preparation of scenarios and mission analyses is best done by experienced CF personnel. Thus responsibility for scenario preparation must be made clear. System scenarios could be deliverables.

3.2.1.1 Defining and Allocating System Functions - The functions that must be performed by the system in achieving its objective(s) within specified mission environments shall be analyzed. Human engineering principles and criteria shall be applied to specify personnel-equipment/ software performance requirements for system operation, maintenance and control functions and to allocate system functions to (1) automatic operation/maintenance, (2) manual operation/maintenance, or (3) some combination thereof. Function allocation is an iterative process achieving the level of detail appropriate for the level of system definition.

This section covers the analysis of system functions. The section can be used to cover the "specification of performance goals & criteria" as required in Table 3. The extent of iteration needed to achieve "the level of detail appropriate for the level of system definition" must be agreed upon and defined.

3.2.1.1.1 Information Flow and Processing Analysis - Analyses shall be performed to determine basic information flow and processing required to accomplish the system objective and include decisions and operations without reference to any specific machine implementation or level of human involvement.

Data Flow Diagrams, State Transition Diagrams, etc. which are often used in the analysis and description of proposed information systems can be used for this activity. There is an opportunity here to show how the human engineering analysis effort will be integrated with other systems engineering efforts to avoid duplication of effort.

3.2.1.1.2 Estimates of Potential Operator/Maintainer Processing Capabilities - Plausible human roles (e.g., operator. maintainer, programmer, decision maker, communicator, monitor) in the system shall be identified. Estimates of processing capability in terms of load, accuracy, rate and time delay shall be prepared for each potential operator/maintainer information processing function. These estimates shall be used initially in determining allocation of functions and shall later be refined at appropriate times for use in definition of operator/maintainer information requirements and control, display and communication requirements. In addition, estimates shall be made of the effects on these capabilities likely to result from implementation or nonimplementation of human engineering design recommendations. Results from studies in accordance with 3.2.2.1 may be used as supportive inputs for these estimates.

In practice it is difficult to make such estimates of processing capability, and few analyses include the type of information required (Beevis , 1987). The section should be re-written to cover the User Analysis which is a feature of a user-centred approach. This would identify the potential user's capabilities in ways related to the task, for example, whether the users have typing skills.

3.2.1.1.3 Allocation of Functions - From projected operator/maintainer performance data, estimated cost data, and known constraints, the contractor shall conduct analyses and tradeoff studies to determine which system functions should be machine-implemented or software controlled and which should be reserved for the human operator/maintainer.

Computer-based information systems can either mechanize the transfer of information, without changing operator functions, or they can change the allocation of functions by automating operator tasks associated with sensing, collating information, or decision making. This is the issue of 'automating a manual system vs. building an automated system' (Beevis et al., 1993). To deal with the allocation of functions, the ARDS/ADM project developed a two-stage function allocation process, wherein functions are allocated initially to humans or to software, and those which are ambiguous are re-examined for implementation by a human assisted by software (Essens et al., 1994).

3.2.1.2 Equipment Selection - Human engineering principles and criteria shall be applied along with all other design requirements to identify and select the particular equipment to be operated/maintained/ controlled by personnel. The selected design configuration shall reflect human engineering inputs, expressed in quantified or "best estimate" quantified terms, to satisfy the functional and technical design requirements and to insure that the equipment will meet the applicable criteria contained in MIL-STD-1472, as well as other human engineering criteria specified by the contract.

MIL-STD-1472D does not deal thoroughly with all aspects of human-computer interaction. Another standard should be identified and used in the SOR, or a user interface style guide should be agreed upon. The style should be based on user profiles. In ARDS/ADM it was agreed that the TCCCS communications back plane would be used, which determines some of the user interface. However, the 'look and feel' of an interface is a function of the dynamics of operator use, and emerges from the interaction between user and machine. Therefore it cannot be completely determined by written standards, and must be verified by prototyping.

3.2.1.3 Analysis of Tasks - Human engineering principles and criteria shall be applied to analyses of tasks.

This sub-section requires no modification.

3.2.1.3.1 Gross Analysis of Tasks - The analyses shall provide one of the bases for making design decisions; e.g., determining, to the extent practicable, before hardware fabrication, whether system performance requirements can be met by combinations of anticipated equipment, software, and personnel, and assuring that human performance requirements do not exceed human capabilities. These analyses shall also be used as basic information for developing preliminary manning levels; equipment procedures; skill, training and communication requirements; and as Logistic Support Analysis inputs, as applicable. Those gross tasks identified during human engineering analysis which are related to end items of equipment to be operated or maintained by personnel and which require critical (see 6.2.1) human performance, reflect possible unsafe practices or are subject to promising improvements in operating efficiency shall be further analyzed, with the approval of the procuring activity.

The gross analysis of tasks should be used to identify those tasks which require prototyping, because they "require critical (see 6.2.1) human performance, reflect possible unsafe practices or are subject to promising improvements in operating efficiency."

3.2.1.3.2 Analysis of Critical Tasks - Further analysis of critical tasks shall identify the: (l) information required by operator/maintainer, including cues for task initiation; (2) information available to operator/ maintainer; (3) evaluation process; (4) decision reached after evaluation; (5) action taken; (6) body movements required by action taken; (7) workspace envelope required by action taken; (8) workspace /available; (9) location and condition of the work environment; (10) frequency and tolerances of action; (11) time base; (12) feedback informing operator/ maintainer of the adequacy of actions taken; (13) tools and equipment required; (14) number of personnel required, their specialty and experience; (15) job aids or references required; (16) communications required, including type of communication; (17) special hazards involved; (18) operator interaction where more than one crew member is involved; (19) operational limits of personnel (performance); and (20) operational limits of machine and software. The analysis shall be performed for all affected missions and phases including degraded modes of operation.	Contractors seldom provide all the information called up in this section (Beevis, 1987). Critical tasks should be examined by prototyping, or simulation, wherever possible.
3.2.1.3.3 Workload Analysis - Individual and crew workload analysis shall be performed and compared with performance criteria.	The section could be modified to include the comparison of results from prototyping or simulation with predictions of operator workload and performance criteria. In addition, the section should address the issue of system manning, and the preparation of the system manning plan.
3.2.1.3.4 Concurrence and Availability - Analyses of tasks shall be modified as required to remain current with the design effort and shall be available to the procuring activity.	No such clause governs the Test and Evaluation efforts. The clause should be modified to state that analyses of functions, tasks, and interface design requirements shall be modified to remain current with the design and prototyping effort.
3.2.1.4 Preliminary System and Subsystem Design - Human engineering principles and criteria shall be applied to system and subsystem designs represented by design criteria documents, performance specifications, drawings and data, such as functional flow diagrams, system and subsystem schematic block diagrams, interface control drawings, overall layout drawings and related applicable drawings provided in compliance with contract data requirements. The preliminary system and subsystem configuration and arrangement shall satisfy personnel-equipment/software performance requirements and comply with applicable criteria specified in MIL-STD-1472 as well as other human engineering criteria specified by the contract.	This section should include reference to rapid prototypes. The requirement "The preliminary system and subsystem configuration and arrangement shall satisfy personnel-equipment/software performance requirements and comply with applicable criteria specified in MIL-STD-1472D as well as other human engineering criteria specified by the contract" should specifically mention the target users and the training plan.

3.2.2 Human Engineering in Equipment Detail Design - During detail design of equipment, the human engineering inputs, made in complying with the analysis requirements of paragraph 3.2.1 herein, as well as other appropriate human engineering inputs, shall be converted into detail equipment design features. Design of the equipment shall meet the applicable criteria of MIL-STD-1472 and other human engineering criteria specified by the contract. Human engineering provisions in the equipment shall be evaluated for adequacy during design reviews. Personnel assigned human engineering responsibilities by the contractor shall participate in design reviews and engineering change proposal reviews of equipment end items involving personnel interfaces. Human engineering requirements during equipment detail design are specified in paragraphs 3.2.2.1, 3.2.2.2, 3.2.2.3, 3.2.2.4 and 3.2.2.5 herein.

The requirement could be expanded to cover prototyping of the interfaces. Any of the following three sub-sections could address prototyping. Although "Mockups and Models" and "Dynamic Simulation" could cover prototyping activities, they are a test or experimental activity.

3.2.2.1 Studies, Experiments and Laboratory Tests - The contractor shall conduct experiments, tests (including dynamic simulation per paragraph 3.2.2.1.2), and studies required to resolve human engineering and life support problems specific to the system. Human engineering and life support problem areas shall be brought to the attention of the procuring activity, and shall include the estimated effect on the system if the problem is not studied and resolved. These experiments, tests, and studies shall be accomplished in a timely manner, i.e., such that the results may be incorporated in equipment design. The performance of any major study effort shall require approval by the procuring activity.

This sub-section should be expanded to include any planned prototyping activities. The outcome of prototyping can be described by the relevant DID (DI-HFAC-80743 Human Engineering Test Plan).

3.2.2.1.1 Mockups and Models - At the earliest practical point in the development program and well before fabrication of system prototypes, full-scale three-dimensional mockups of equipment involving critical human performance shall be constructed. The proposed Human Engineering Program Plan shall specify mockups requiring procuring activity approval and modification to reflect changes. The workmanship shall be no more elaborate than is essential to determine the adequacy of size, shape, arrangement, and panel content of the equipment for human use. The most inexpensive materials practical shall be used for fabrication. These mockups and models shall provide a basis for resolving access, workspace and related human engineering problems, and incorporating these solutions into systems design. Upon approval by the procuring activity, scale models may be substituted for mockups. In those design areas where systems/equipment involve critical human performance and where human performance measurements are necessary, functional mockups shall be provided, subject to prior approval by the procuring activity. The mockups shall be available for inspection as determined by the procuring activity. Disposition of mockups and models, after they have served the purposes of the contract, shall be as directed by the procuring activity.

This requirement need not be modified if prototyping is dealt with under 3.2.2.1. Mockups and models may have some value in testing and training. Reference should be made to such uses.

3.2.2.1.2 Dynamic Simulation - Dynamic simulation techniques shall be utilized as a human engineering design tool when necessary for the detail design of equipment requiring critical human performance. Consideration shall be given to use of various models for the human operator, as well as man-in-the-loop simulation. While the simulation equipment is intended for use as a design tool, its potential relationship to, or use as, training equipment shall be considered in any plan for dynamic simulation.

It seems best to leave this sub-section to cover activities such as computer simulation of operator task networks (i.e., analysis) and not to include prototyping.

3.2.2.3 Work Environment, Crew Stations and Facilities Design - Human engineering principles and criteria shall be applied to detail design of work environments, crew stations and facilities to be used by system personnel. Drawings, specifications and other documentation of work environment, crew stations and facilities shall reflect incorporation of human engineering requirements and compliance with applicable criteria of MIL-STD-1472 and other human engineering criteria specified by the contract. Design of work environment, crew stations and facilities which affect human performance, under normal, unusual and emergency conditions, shall consider at least the following where applicable:

The requirement emphasizes physical aspects of the design, and not all the items covered are relevant to CCIS.

a. Atmospheric conditions, such as composition, volume, pressure and control for decompression, temperature, humidity and air flow.

b. Weather and climate aspects, such as hail snow, mud, arctic, desert and tropic conditions.

c. Range of accelerative forces, positive and negative, including linear, angular and radial.

d. Acoustic noise (steady state and impulse), vibration, and impact forces.

e. Provision for human performance during weightlessness.

f. Provision for minimizing disorientation.

g. Adequate space for personnel, their movement, and their equipment.

h. Adequate physical, visual, and auditory links between personnel and personnel and their equipment, including eye position in relation to display surfaces, control and external visual areas.

i. Safe and efficient walkways, stairways, platforms and inclines.

j. Provisions for minimizing psychophysiological stresses.

k. Provisions to minimize physical or emotional fatigue, or fatigue due to work-rest cycles.

l. Effects of clothing and personal equipment, such as full and partial pressure suits, fuel handler suits, body armor, polar clothing, and temperature regulated clothing.

m. Equipment handling provisions, including remote handling provisions and tools when materiel and environment require them.

n. Protection from chemical, biological, toxicological, radiological, electrical and electromagnetic hazards.

o. Optimum illumination commensurate with anticipated visual tasks.

p. Sustenance and storage requirements (i.e., oxygen, water and food), and provision for refuse management;

q. Crew safety protective restraints (shoulder, lap and leg restraint systems, inertia reels and similar items) in relation to mission phase and control and display utilization.

3.2.2.4 Human Engineering in Performance and Design Specifications - The provisions of performance and design specifications prepared by the contractor, shall conform to applicable human engineering criteria of MIL-STD-1472 and other human engineering criteria specified by the contract.

MIL-STD-1472D establishes design standards, not performance criteria. Overall human factors performance criteria for the system should be established during the requirements definition phase. The text should be modified to reflect this.

3.2.2.5 Equipment Procedure Development - Based upon the human performance functions and tasks identified by human engineering analyses (3.2.1 herein), the contractor shall apply human engineering principles and criteria to the development of procedures for operating, maintaining or otherwise using the system equipment. For computer systems where operating and maintenance procedures are largely determined by software programs, human engineering shall be applied throughout the software program planning and development. This effort shall be accomplished to assure that the human functions and tasks identified through human engineering analysis are organized and sequenced for efficiency, safety and reliability, to provide inputs to the Logistic Support Analysis where required, and to assure that the results of this effort shall be reflected in the development of operational, training and technical publications.

No changes required.

3.2.3 Human Engineering in Test and Evaluation - The contractor shall establish and conduct a test and evaluation program to: (1) assure fulfillment of the applicable requirements herein; (2) demonstrate conformance of system, equipment and facility design to human engineering design criteria; (3) confirm compliance with performance requirements where personnel are a performance determinant; (4) secure quantitative measures of system performance which are a function of the human interaction with equipment; and (5) determine whether undesirable design or procedural features have been introduced. (The fact that these functions may occur at various stages in system, subsystem, or equipment development shall not preclude final human engineering verification of the complete system. Both operator and maintenance tasks shall be performed as described in approved test plans during the final system test.)

Test and Evaluation (T&E) has the following aims:

1. Assure fulfillment of the applicable requirements
2. Demonstrate conformance of the system, equipment, and facility design to human engineering design criteria,
3. Confirm compliance with performance requirements where personnel are a major determinant
4. Secure quantitative measures of system performance ....,
5. Determine whether undesirable features have been introduced.

The requirement should be revised to include:

- Concept demonstration
- Assurance of operability by the intended users in the intended environment
- Demonstration of the effectiveness of the Training Plan
- That the planned activities will be integrated with those of requirements definition and prototyping.

3.2.3.1 Planning - Human engineering testing shall be incorporated into the system test and evaluation program and shall be integrated into engineering design and development tests, contractor demonstrations, flight tests, R&D acceptance tests and other development tests. Compliance with human engineering requirements shall be tested as early as possible. Human engineering findings from design reviews, mock-up inspections, demonstrations and other early engineering tests shall be used in planning and conducting later tests. Human engineering test planning shall be directed toward verifying that the system can be operated, maintained, supported and controlled by user personnel in its intended operational environment. Test planning shall include methods of testing (e.g., use of checklists, data sheets, test participant descriptors, questionnaires, operating procedures and test procedure), schedules, quantitative measures, test criteria and reporting processes.

The main thrust to Test and Evaluation (T&E) is to demonstrate that the system will meet performance requirements. Given the need for an iterative approach to the development of CCIS, T&E activities should occur throughout the development cycle. The T&E plan should reflect this, and show how performance requirements will be identified and tested. The plan must be cross-referenced to the user participation activities, plans for rapid prototyping, and the Training Plan.

3.2.3.2 Implementation - The human engineering test and evaluation plan, shall be implemented upon approval by the procuring activity. Test documentation (e.g., checklists, data sheets, test participant descriptors, questionnaires, operating procedures, test procedures) shall be available at the test site. Human engineering portions of all tests shall include the following:

The first item could be expanded to include prototyping.

a. A simulation (or actual conduct where possible) of mission or work cycle).

b. Tests in which human participation is critical as defined in paragraph 6.2.1.

c. A representative sample of non-critical scheduled and unscheduled maintenance tasks that do not duplicate the tasks selected for the maintainability demonstration.

d. Proposed job aids, new equipment training (NET) programs, training equipment, and special support equipment.

e. Utilization of personnel who are representative of the range of the intended military user populations in terms of skills, size and strength and wearing suitable military garments and equipment which are appropriate to the tasks and approved by the procuring activity. (Use of military personnel from the intended user population is preferred where feasible.)

f. Collection of task performance data in simulated or, where possible, actual operational environments.

g. Identification of discrepancies between required and obtained task performance.

h. Criteria for acceptable performance of the test.

3.2.3.3 Failure Analysis - All failures occurring during test and evaluation shall be subjected to a human engineering review to differentiate between failures due to equipment alone, personnel-equipment incompatibilities and those due to human error. The contractor shall notify the procuring activity of design conditions which may contribute substantially to human error and shall propose appropriate solutions to these conditions.

Failures should include software-related failures which might be due to human factors such as poor interface design or short term memory failure in handling alphanumerics.

3.2.4 Cognizance and Coordination - The human engineering program shall be coordinated with maintainability, system safety, reliability, survivability/ vulnerability, facilities engineering, integrated logistic support, and other human factors engineering functions including bio-medical, life support, personnel and training, and shall be integrated into the total system program. Results of human engineering test and evaluation shall be incorporated into the Logistic Support Analysis Record (LSAR) as applicable. The human engineering portion of any analysis, design or test and evaluation program shall be conducted under the direct cognizance of personnel assigned human engineering responsibility by the contractor.	No changes required.
3.3 Data Requirements - All human engineering data requirements shall be as specified by the contract.	No changes required.
3.3.1 Traceability. - The contractor shall appropriately document his human engineering efforts to provide traceability from the initial identification of human engineering requirements during analysis and/or system engineering through design and development to the verification of these requirements during test and evaluation of approved design, software and procedures.	No changes required.
3.3.2 Access. - All data, such as plans, analyses, design review results, drawings, checklists, design and test notes, and other supporting back ground documents reflecting human engineering actions and decision rationale, shall be maintained and made available at the contractor's facilities to the procuring activity for meetings, reviews, audits, demonstrations, test and evaluation, and related functions.	No changes required.
3.4 Drawing Approval - Personnel assigned human engineering responsibility by the contractor shall approve all layouts and drawings having potential impact on human interface with the system, equipment, or facility.	Should include all representations of the user interface, including story boards, prototypes, mockups, and simulations.
4. QUALITY ASSURANCE	No changes required

Compliance with the requirements of this specification and other human engineering requirements specified by the contract will ultimately be demonstrated by the system's ability to meet its mission and operational objectives. During the development program, compliance with the human engineering requirements, as they pertain to system design and effectiveness, will be demonstrated at the scheduled design and configuration reviews and inspections as well as during development test and evaluation inspections, demonstrations and tests.

6.1 Intended Use - This specification may be invoked in its entirety or selectively as prescribed by the procuring activity. The primary use of this specification for procurement does not necessarily preclude its utilization for in-house efforts, where desired. Compliance with this specification will provide the procuring activity with assurance of positive management control of the human engineering effort required in the development and acquisition of military systems, equipment and facilities. Specifically, it is intended to assure that: a. System requirements are achieved by appropriate use of the human component. b. Through proper design of equipment, software and environment, the personnel-equipment/software combination meets system performance goals. c. Design features will not constitute a hazard to personnel. d. Trade-off points between automated vs. manual operation have been chosen for peak system efficiency within appropriate cost limits. e. Human engineering applications are technically adequate. f. The equipment is designed to facilitate required maintenance. g. Procedures for operating and maintaining equipment are efficient, reliable and safe. h. Potential error-inducing equipment design features are minimized. i. the layout of the facility and the arrangement of equipment affords efficient communication and use. j. The contractors provide the necessary manpower and technical capability to accomplish the above objectives.	No changes required

Relationship to other systems development activities

As noted earlier, a complete user-centred approach to CCIS acquisition or development includes work items such as stakeholder identification and scenario development which may be performed best by the PMO. The complete HEPP for a project would include those activities, and the contractor's HEPP must make it clear what inputs they expect from the PMO.

Many HFE activities parallel the mainstream systems engineering activities (NATO AC/243 (Panel-8)TR/7, 1992) and should be also associated with logistics support and personnel sub-system development. However, those activities must be integrated if full benefit is to be obtained from them. The HEPP, the systems engineering management plan, and the software development plan should be delivered as part of the contractor's proposal package.

The generic HEPP refers to the Training plan and to a T&E plan. The list of deliverables (Table 6) also refers to a 'manning and training plan' and a 'training plan.' The Training and T&E Plans may be separate documents, as they are dealt with separately from HFE by several regulatory documents which may be used by the PMO (US MIL-STD-490A, MIL-STD-1388-2B, MIL-STD-1521B).

Schedule, Meetings, Reviews and Deliverables

The review points and deliverables in the HFE process are listed in Table 4. The 'user acceptance plan' and the plans for user participation and rapid prototyping, which are mentioned in the generic HEPP, should be an integral part of the HEPP. They are deliverables which should be specified in the HEPP.

Table 4: Review points and deliverables in the User Engineering Process
(from Beevis et al., 1993)

1. CONTRACT READINESS REVIEW (CRR)

a. Issues to be examined
- Human Engineering Program Plan
- Stakeholder & User Participation
- Organization of User Engineering Steering Group

2. SYSTEM REQUIREMENTS REVIEW (SRR) (Preliminary user-design review)

Issues to be examined
- Work flows
- Organization
- System Concept
- Allocation of Functions

Information to be reported
- Scenarios & performance specifications
- Mission and Function Analyses
- Prototypes
- Draft manning & training plan
- Plan for resolving issues
- Draft requirements specification

3. SYSTEM DESIGN REVIEW (SDR) (Includes User Design Review)

Issues to be examined
- Work station details

Information to be reported
- Prototype baseline and performance data
- Requirements specification
- Training plan
- User acceptance plan

4. PRELIMINARY DESIGN REVIEW (PDR)

Information to be reported
- interface standards & guidelines

5. CRITICAL DESIGN REVIEW (PDR)

Information to be reported
- Design configuration documents

6. SYSTEM ACCEPTANCE
- Data obtained from replaying scenarios from SRR

Evaluation of proposed HEPP

HEPP are best evaluated with the assistance of subject matter experts representing both human factors specialists and project specialists. When evaluating a contractor's HEPP, project personnel must consider a number of factors:

Technical proposal:
- Does the proposal show understanding of scope and objectives of the work?
- Is the proposed approach sound?
- Does the plan identify the input required from PMO and system users?
- Does the HEPP show the relationship between HFE, manpower, personnel and training, system safety, test and evaluation, and systems engineering activities?
- Work items:
  - do they propose, or have they completed, HFE work items, as identified in Table 1?
  - how will user input be obtained?
  - what is the completion action for each work item? does it include a report?
  - how will acceptance criteria for the work item products be defined?
  - do they propose a list of deliverables as outlined in Table 4?
- Is the timescale and level of effort practical?
- Are personnel loadings shown for each activity?
- Are regular review points scheduled?
- Will the results of the HFE effort be timely for the overall project effort?

Team capabilities & experience:
- Does the team include a human factors specialist?
- What experience does the team have in user-centred development?
- What experience do they have in designing for military users?
- Have they experience in performance measurement and user trials?

CONCLUSIONS AND RECOMMENDATIONS

Human Factors Engineering has gained wide acceptance in the design of the human computer interface. However, most software development, whether custom or COTS, has yet to fully integrate HFE techniques into the software engineering process. A case can be developed for the inclusion of HFE in CCIS development on the basis of either usability or cost. This report was written to address the integration of HFE with the development of CCIS, to present the user-centred development process, and to propose a draft of a generic project plan for the application of HFE in CCIS.

Much of the documentation governing the development of systems and/or software does not emphasize HSI or HFE. Observation of the ARDS/ADM project showed that even with PMO encouragement, the integration of HFE with other systems engineering activities is far from assured.

A review of several approaches to the development of system software showed that they do not place a strong emphasis on HFE or user requirements. New approaches to software engineering could facilitate the integration of HFE in the system engineering process. The METHOD/1 toolset, being adopted by DND, combined with a move toward more object-oriented analysis, design, and coding, offer attractive opportunities to integrate HFE in software engineering. It is concluded, that HFE can be included into various approaches to software development provided that such activities are planned for.

User-centred design is a new development in software engineering which emphasizes the human in system design. While several different approaches to user-centred design have been reported recently, all emphasize user involvement in the design process, prototyping and iterative development, and testing against usability criteria. Scenarios, mission analyses and functional decompositions are very effective for obtaining user input. Prototyping is the key to user-centred design, but it must be applied with skill and towards specific goals, and it must be balanced by analysis.

An effective Human Engineering Programme Plan documents the agreement between contractor and procuring agency on the extent and scope of HFE activities and their relationship to other systems engineering efforts. US MIL-H-46855B contains the essential ingredients of a good HEPP, but some additions are required. The HEPP should be detailed, but information requirements should be realistic and unnecessary studies avoided. The HEPP should define human engineering activities to be carried out during project phases and it should specify deliverables. Manning, training, and testing issues should be considered. Other standards and references can be invoked by the HEPP for specific issues.

There is a need to continue to emphasize the integration of HFE in CCIS. CRAD/DRDL is sponsoring work at DCIEM aimed at the development of a course in HFE for project managers. The work will also revise and expand the draft HEPP included in this report. If the METHOD/1 software design methodology becomes required by DND for CF acquisition projects, then the creation of HFE segments, tasks and work steps should be investigated. Observations of the ARDS/ADM project will continue under contract to DCIEM and the results will be used to further develop this plan to integrate HFE in CCIS, in a process that is intended to be acceptable to project managers and contractors.

REFERENCES

ADGA (1994). *Conceptual enterprise model and architectural framework: establishing the foundation for integrating electronic performance support within the Land Software Engineering Center,* Report for DND, Hull, Quebec: ADGA (Quebec) Ltée.

Andriole, S.J. (1990). *Getting it right!: Information system design principles for the 90s.*, Fairfax, VA: AFCEA International Press.

ANSI/AIAA, (1992). *Guide to human performance measurements*, Washington DC: American Institute of Aeronautics and Astronautics.

APEO, (1993). *Guideline for the use of computer software tools by professional engineers and the development of computer software affecting public safety or welfare,* Toronto: Association of Professional Engineers of Ontario.

Beevis, D., (1987). Experience in the integration of human engineering effort with avionics systems development. In: *The design, development and testing of complex avionics systems,* AGARD-CP-417, Neuilly-sur-Seine, France: Advisory Group for Aerospace Research and Development, pp. 27 1-9.

Beevis, D., and Slade, I.M., (1970). Ergonomics - costs and benefits, *Applied Ergonomics, 1*, (2), 79-84.

Beevis, D., and St Denis, G. (1992). Rapid prototyping and the human factors engineering process, *Applied Ergonomics, 23,* (3), 155-160.

Beevis, D., Essens, P., and Mack, I. (Eds.). (1993). *The application of human factors engineering in the development of command and control information systems for the Canadian Forces.*, (Report 93-42), Toronto: DCIEM.

Behavioural Team (1991). *Ergonomic considerations in command and control systems.* Report to Midi-Plus Consultants for Defence Research Establishment Valcartier. Toronto: Author

Berard, E.V., (1993). *Essays on object-oriented software engineering*, Volume I. Englewood Cliffs, New Jersey: Prentice Hall.

Booher, H.R. and Rouse, W.B. (1990). MANPRINT as the competitive edge, In: H.R. Booher (Ed.), *MANPRINT - an approach to systems integration,* (pp. 575-594). New York: Van Nostrand Reinhold.

Chapanis, A. (1991a). The business case for human factors in informatics, In: In: B. Shackel and S. Richardson (Eds.), *Human factors for informatics usability,* (Part 1, Chapter 3, pp. 39 - 71). Cambridge: Cambridge University Press.

Chapanis, A. (1991b). Evaluating usability, In: B. Shackel and S. Richardson (Eds.), *Human factors for informatics usability,* (Part 5, Chapter 16, pp. 359 - 395). Cambridge: Cambridge University Press.

Coad, P. and Yourdon, E. (1991). *Object-oriented analysis*, 2ed. Englewood Cliffs, New Jersey: Yourdon Press.

Copas, C.V., Triggs, T.J., and Manton, J.G. (1985). *Human factors in command-and-control system procurement,* Human Factors Report HFR-15 for the Commonwealth Department of Defence, Melbourne, Australia: Monash University.

Defense Information Systems Agency (1992). *Human computer interface style guide, Version 2.0.* Washington: Department of Defense, Center for Information Management.

Diaper, D. (1989). *Task analysis for human-computer interaction.*, Chichester, West Sussex, U.K.: Ellis Horwood.

Digitalk Inc.(1991). *Smalltalk V / PM tutorial and programming handbook,* Los Angeles CA: Digitalk.

DIS Arch (1993). *Draft information technology management directive (ITMD) systems development methodology.* 1243-CIMS, DIS Arch, (21 December). Ottawa: National Defence Headquarters, Department of National Defence.

DND, (1969). *Engineering Standard: Definitions of systems effectiveness terms for reliability, maintainability, human factors and safety,* DND-ENG. STD-3, Defence Headquarters, Department of National Defence, Canada.

DND, (1979). *Specification preparation - technical content,* D-01-300-100/SG-000. Ottawa: Department of National Defence.

DND, (1987). *Project management,* Volumes 1-7, A-LP-005-000/001 to 007 . Ottawa: Department of National Defence.

Eason, K.D., (1982). The process of introducing information technology, *Behaviour and Information Technology,* 1 (2), 197-213.

Eason K.D. (1990). *Information technology and organisational change,* London and Philadelphia: Taylor and Francis, ISBN 0-85066-391-1

Engel and Townsend, (1989). *Guidelines for the design and evaluation of operator interfaces for computer based control systems,* (Contract report for DCIEM), Toronto, Ontario: Author.

Engel and Townsend, (1991). *Division command and control performance measurement,* (Contract report for DCIEM), Toronto, Ontario: Author.

Gorrell, E.L. (1979). *Human engineering design requirements for SHINMACS machinery control consoles: Part I: operator information and control requirements,* (Unpublished report), Toronto: DCIEM.

Gorrell, E.L. (1980). *Human engineering design requirements for SHINMACS machinery control consoles: Part II: console hardware and functions,* (Report 80-R-27), Toronto: DCIEM.

Gorrell, E.L. (1981). *Human engineering design requirements for SHINMACS machinery control consoles: Part I: operator information and control requirements,* (Report 81-R-18), Toronto: DCIEM.

Hatley, D.J. and Pirbhai, I.A., (1988). *Strategies for real time system specification*, New York: Dorset House Publishing.

Helleur, C., Richardson, Capt J., Roy, S., (1994). *Requirements capture and prototyping for airlift information system,* (Report DREV M-3185/94), Valcartier, Quebec: Defence Research Establishment Valcartier.

Hendricks, D.E., Kilduff, P.W., Brooks, P., Marshak, R., & Doyle, B. (1983). *Human engineering guidelines for management information systems. Appendix A. Common Problems,* US Army Aberdeen Proving Ground, MD: Management Information Systems Directorate and Human Engineering Laboratory.

HMSO, (1988). *Human factors guidelines for the design of computer-based systems, Volumes 1-6*. London: HMSO and Department of Trade and Industry.

Human*Systems* Inc., (1993). *Survey of evaluation methods for command and control systems,* (Report prepared for DCIEM under contract: W7711-2-7178/01-XSE), Milton, Ontario: Author.

Johnson, K. P., Diaper, D., and Long, J.B. (1984). Tasks, Skills and Knowledge: Task Analysis for Knowledge Based Descriptions. In Shackel, B. (ed.). *INTERACT '84 - Proceedings of the first IFIP conference on human-computer interaction.* Amsterdam: North-Holland.

Jordan, P.W. , (1994). Focus groups in usability evaluation and requirements capture: a case study, In: E.J. Lovesey (Ed.) *Contemporary ergonomics 1994: Proceedings of the Ergonomics Society's annual conference*. London: Taylor and Francis.

Mayer, R.J., Keen, A., and Wells, M.S. (1992). *Information integration for concurrent engineering (IICE), IDEF4 object-oriented design method report*, Air Force Systems Command: Armstrong Laboratory.

McLaughlin, L. (1987). *User engineering, a new look at system engineering,* Redondo Beach, CA: TRW Defense Systems.

Marton, T., and Toomer, L.A., (1989). The role of MANPRINT in non-developmental items acquisition, *MANPRINT Bulletin*, III (6), May/June.

Melkus, L.A. and Torres, R.J., (1988). Guidelines for the use of a prototype in user interface design, *Proceedings of the Human Factors Society 32nd annual meeting,* Santa Monica: Human Factors Society.

Metersky, M.L. (1993), A decision-oriented approach to system design and development, *IEEE Transactions on Systems, Man, and Cybernetics, 23* (4), 1024-1057.

NATO AC/243 Panel-8 (1984). *Proceedings of the workshop on applications of systems ergonomics to weapon system development,* (Report AC/243 DS/A/DR(84)408), Brussels: NATO Defence Research Group.

NATO AC/243 Panel-8/RSG.12 (1989). *Computer-Human Interaction in Command and Control,* (Report AC/243(Panel 8)D/7). Brussels: NATO Defence Research Group.

NATO AC/243 Panel-8/RSG.14 (1992). *Analysis techniques for man-machine system design,* Volumes 1 & 2, (Report AC/243(Panel 8)TR/7). Brussels: NATO Defence Research Group.

NATO AC/243 Panel-8/RSG.19 (1991). *Toward a framework for Cognitive Analysis, Design, and Evaluation (COADE).* (Draft paper for workshop on Decision aiding in Command and Control), 2-3 June 1992, Washington D.C. RSG.19/4/13, Soesterberg, The Netherlands.

Nickerson, R.S. & Pew, R.W. (1990). Toward more compatible human-computer interfaces. *IEEE Spectrum* 40-43.

Nielsen, J. (1993). *Usability engineering,* San Diego, CA: Academic Press.

Norman, D.A., & Draper, S.W. (Eds.) (1986). *User centred system design: new perspectives on human-computer interaction.* Hillsdale, N.J.: Lawrence Erlbaum Associates Inc.

OED (1933). *The shorter Oxford English dictionary,* Oxford: The Clarendon Press.

Overmyer, S.P., (1990). The impact of DoD-STD-2167A on iterative design methodologies: help or hinder? *ACM Software Engineering Notes, 15* (5), 50-58.

Pressman, R.S. (1987). *Software engineering: a practitioners approach,* New York: McGraw-Hill.

Rouse, W.B. (1991). *Design for success: a human-centered approach to designing successful products and systems,* New York: Wiley Interscience.

Seaton, P., and Stewart, T. (1992). Evolving task oriented systems. In: P. Bauersfeld, J. Bennett, G. Lynch (Eds.) *CHI '92 - Striking a balance, Proceedings of the conference on human factors in computer systems. ACM/CHI,* Reading, Massachusetts: Addison -Wesley.

Steiner, B.A., and Ims, J.R. (1991). *Human engineering requirements for rapid prototyping of operator/maintainer interfaces.* Aerospace Report No. TOR-92(2904)-1, (The Aerospace Corporation), Los Angeles: Space Systems Division, US Air Force Systems Command.

Sweet, R., Metersky, M., and Sovereign, M., (1986). *Proceedings of the MORS command and control evaluation workshop,* Washington D.C.: Military Operations Research Society.

US ARI (1988). *MANPRINT handbook for nondevelopmental item (NDI) acquisition,* (Report AMC PAM 602-2), Washington D.C.: US Army Research Institute.

US Department of the Army, (1990). *Manpower and personnel integration (MANPRINT) in the materiel acquisition process,* Army Regulation 602-2, Washington D.C.: Author.

US DoD (1979). *Military Specification MIL-H-46855B -Human engineering requirements for military systems, equipment and facilities,* Washington D.C.: US Department of Defense.

US DoD (1985). *Military Standard 1521 B (USAF) - Technical reviews and audits for systems, equipments, and computer software.,* Washington D.C.: US Department of Defense.

US DoD (1987). *DI-HFAC-80740 Human engineering program plan*, Washington D.C.: US Department of Defense.

US DoD (1988). *DOD-STD-2167A Defense system software development*. Washington D.C.: US Department of Defense.

US DoD, (1991). *Defense acquisition management policies and procedures*, (Department of Defense Instruction No. 5000.2), Washington D.C.: US Department of Defense.

US DoD (1992). *Human Computer Interface Style Guide, Version 2.0*, Washington D.C.: US Defense Information Systems Agency.

US GAO, (1981). *Guidelines for assessing whether human factors were considered in the weapon systems acquisition process* (Report FPCD-82-5), Washington D.C.: United States General Accounting Office.

Walsh, P. (1989). Analysis for Task Object Modelling (ATOM): towards a method of integrating task analysis with Jackson System Development for user interface software design, In: D. Diaper, D. (Ed.). *Task analysis for human-computer interaction.*, Chapter 6. Chichester, West Sussex, U.K.: Ellis Horwood.

Williges, R.C., Williges, B.H., Elkerton, J. (1987). Software interface design. In: G. Salvendy (Ed.). *Handbook of human factors*, Chapter 11.3. New York: Wiley Interscience.

Whiteside, J., Bennett, J., and Holtzblatt (1988). Usability engineering: our experience and evolution. In: M. Helander (Ed.), *Handbook of human-computer interaction*, (Chapter 39). North Holland: Elsevier Science Publishers B.V.

LIST OF ABBREVIATIONS

ADM - Associate Deputy Minister
ARDS - Artillery Regimental Data System
CASE - Computer Aided Software Engineering
CCIS - Command and Control Information System
COTS - Commercial Off-the-Shelf
CRAD - Chief of Research and Development
CSCI - Computer Software Configuration Item
CSC - Computer Software Component
CSU - Computer Software Unit
DCIEM - Defence and Civil Institute of Environmental Medicine
DID - Data Item Description
DND - Department of National Defence
DoD - US Department of Defense
DPM - Deputy Project Manager
DPMS - Defence Programme Management System
DRDL - Director, Research and Development, Land
HE - Human Engineering
HEMP - Human Engineering Management Plan
HEPP - Human Engineering Project Plan
HFE - Human Factors Engineering, synonymous with Human Engineering
HMSO - Her Majesty's Stationary Office
H-P - Hatley-Pirbhai
HSI - Human Systems Integration
HWCI - Hardware Configuration Item
IAW - In Accordance With
MANPRINT - Manpower and Personnel Integration
OOP - Object-Oriented Programming
PM - Project Manager
PMO - Project Management Office
QA – Quality Assurance
RA - Requirements Analysis
RFP - Request for Proposals
SDM - System Development Methodology
SDR - System Design Review

SE - System Engineering
SOR - Statement of Requirement
SOW - Statement of Work
SRA - System Requirements Analysis
SRR - System Requirements Review
SSS - System Software Specification
TAD - Target Audience Description
TCCCS - Tactical Command, Control and Communications System
T&E - Test and Evaluation
TRLO - Technical Requirements Liaison Officer

GLOSSARY OF TERMS AND DEFINITIONS

allocation of functions – See function allocation.

analysis – The resolution of anything complex into its simple elements.

contractor – An organization, usually in industry, which contracts to perform engineering activities to develop and build a system or equipment.

critical task – A task which, if not accomplished in accordance with system requirements, will have adverse effects on cost, system reliability, efficiency, effectiveness, or safety (after US MIL-H-46855B).

data item description (DID) - a form used to describe the data required from a contractor, each DID being listed in the Contract Data Requirements List (CDRL).

design and development – The phase of an equipment programme which calls for design engineering work aimed at full validation of the technical approach and ensures complete system integration to the point where production contract action can be taken (NATO PAPS).

designer – One who designs or plans or makes patterns for manufacture.

equipment – All non-expendable items needed to outfit/equip an individual or organization (NATO Glossary).

ergonomics – The systematic study of the relation between the human, machine, tools, and environment, and the application of anatomical, physiological, and psychological knowledge to the problems arising therefrom. Synonymous with Human Factors.

function – A broad category of activity performed by a system, usually expressed as a verb + noun phrase, e.g., "control air-vehicle," "update way-point" (NATO STANAG 3994/1). A function is a logical unit of behaviour of a system.

function allocation – The process of deciding how system functions shall be implemented – by human, by equipment, or by both – and assigning them accordingly.

functional analysis – An analysis of system functions describing broad activities which may be implemented by personnel, and/or hardware and/or software.

human engineering (HE) – The area of human factors which applies scientific knowledge to the design of items to achieve effective human-machine integration (after US MIL-H-46855B). Human engineering includes developmental test and evaluation activities.

human factors (HF) – A body of scientific facts about human capabilities and limitations. It includes principles and applications of human engineering, personnel selection, training, life support, job performance aids, and human performance evaluation. Synonymous with Ergonomics.

human-machine system – A composite of equipment, related facilities, material, software and personnel required for an intended operational role.

human systems integration (HSI) – The technical process of integrating the areas of human engineering, manpower, personnel, training, systems safety, and health hazards with a materiel system to ensure safe, effective operability and supportability. Also the title of Part 7, Section B of US DoD Defense Instruction 5000.2 on Defense Acquisition Management Policies and Procedures.

maintainer – An individual responsible for retaining a defence system in, or restoring it to, a specified condition.

manpower – The demand for human resources in terms of numbers and organization.

methodology – The study of method, usually taken to mean an integrated set of methods and rules applicable to some goal.

mission – What a human-machine system is supposed to accomplish, in response to a stated operational requirement (NATO STANAG 3994/1).

mission analysis – A process to determine the operational capabilities of military forces that are required to carry out assigned missions, roles, and tasks in the face of the existing and/or postulated threat with an acceptable degree of risk (NATO PAPS).

mock-up – A model, built to scale, of a machine, apparatus, or weapon, used in studying the construction of, and in testing a new development, or in teaching personnel how to operate the actual machine, apparatus or weapon (NATO Glossary of Terms). A three-dimensional, full-scale replica of the physical characteristics of a system or sub-system (UK DEF STAN 00-25).

operability - quality of combined features and characteristics of equipment that permits or enhances the operation of equipment by personnel of average skill, with maximum safety, under the intended operational conditions, to obtain the required operational performance (DND-ENG. STD-3).

operator – An individual primarily responsible for using a system, or enabling a system to function, as designed.

personnel – The definition of manpower in terms of trade, skill, experience levels, and physical attributes.

reliability – The probability that an item will perform its intended function for a specified interval under stated conditions (CAN DND ENG-STD-3).

RSG – Research Study Group. A group sponsored by one of the NATO Defence Research Group Panels to carry out research on a specific topic.

safety – Freedom from those conditions that can cause death or injury to personnel, damage to or loss of equipment or property, or damage to the environment.

specification – The document which prescribes in detail the requirements to which ... supplies or services must conform. NOTE: It may refer to drawings, patterns, or other relevant documents and may indicate the means and criteria whereby conformance can be checked (AGARD Multilingual Dictionary).

– A document intended primarily for use in procurements which clearly and accurately describes the essential and technical requirements for items, materials, or services, including procedures by which it can be determined that the requirements have been met (CAN A-LP-005-000/AG-006).

standard – An exact value, a physical entity, or an abstract concept, established and defined by authority, custom, or common consent to serve as a reference, model, or rule in measuring quantities, establishing practices or procedures, or evaluating results. A fixed quantity or quality (NATO Glossary of Terms and Definitions).
– A document that establishes engineering and technical limitations and applications for items, materials, processes, methods, designs, and engineering practices (CAN A-LP-005-000/AG-006).

statement of requirement (SOR) – A statement of the capability required of a new system, to meet an existing or postulated threat, synonymous with NATO Staff Target. In the UK it includes estimated costs and technical factors.

story board - A sequence of displays, usually paper drawings, which illustrate how a system may appear when operated.

system – In general a set or arrangement of things so related or connected as to form a unity or organic whole (Webster's New World Dictionary of the American Language, 2nd College Edition, 1970. The Publishing Company).

system design – The preparation of an assembly of methods, procedures, and techniques united by regulated iterations to form an an organized whole (NATO Glossary of Terms).

system effectiveness – The probability that the system will provide, in terms of resources required, and as specified, either:

(a) the maximum operational performance within the total cost prescribed, or
(b) the required value at lowest cost. (CAN DND-ENG-STD-3).

system(s) engineering (SE) – A basic tool for systematically defining the equipment, personnel, facilities and procedural data required to meet system objectives (US MIL-H-46855B).

system requirements analysis (SRA) – An analysis of what is required of a system to identify those characteristics which the system (both personnel and equipment) must have to satisfy the purposes of the system (after UK DEF STAN 00-25).

task – A composite of related operator or maintainer activities (perceptions, decisions, and responses) performed for an immediate purpose, e.g., "insert aircraft position" (after NATO STANAG 3994/1).

task analysis – A time oriented description of personnel-equipment-software interactions brought about by an operator, controller or maintainer in accomplishing a unit of work with a system or item of equipment. It shows the sequential and simultaneous manual and intellectual activities of personnel operating, maintaining, or controlling equipment (US MIL-H-46855B).

Test and Evaluation (T&E) – A comprehensive programme of test activities, conducted throughout the system hierarchy and over the system life cycle, to:

(a) assess system performance
(b) verify conformance to system requirements
(c) determine system acceptability

training – The process by which trainees acquire or enhance specific skills, knowledge, and attitudes required to accomplish military tasks.

usability - the set of attributes that bear on the effort required to use (learn, understand and operator) software and on the individual assessment of such use by a stated or implied set of users (APEO, 1993)

weapon system – A combination of one or more weapons with all related equipment, materials, services, personnel and means of delivery and deployment (if applicable) required for self-sufficiency (NATO Glossary of Terms).

work breakdown structure (WBS) – A matrix of sub-systems and design/development team activities used for project management.

workload – The level of activity or effort required of an operator to meet performance requirements or criteria (Glossary of Ergonomics).

APPENDIX A: LIST OF DIDs INCLUDED IN US DOD STD-2167-A

System/Segment Design Document (SSDD)	DI-CMAN-80534
Software Development Plan (SDP)	DI-CMAN-80030A
Software Requirements Specification (SRS)	DI-MCCR-80025A
Interface Requirements Specification (IRS)	DI-MCCR-80026A
Interface Design Document (IDD)	DI-MCCR-80027A
Software Design Document (SDD)	DI-MCCR-80012A
Software Product Specification (SPS)	DI-MCCR-80029A
Version Description Document (VDD)	DI-MCCR-80013A
Software Test Plan (STP)	DI-MCCR-80014A
Software Test Description (STD)	DI-MCCR-80015A
Software Test Report (STR)	DI-MCCR-80017A
Computer System Operator's Manual (CSOM)	DI-MCCR-80018A
Software User's Manual (SUM)	DI-MCCR-80019A
Software Programmer's Manual (SPM)	DI-MCCR-80021A
Firmware Support Manual (FSM)	DI-MCCR-80022A
Computer Resources Integrated Support Document (CRISD)	DI-MCCR-80024A
Engineering Change Proposal (ECP)	DI-E-3128
Specification Change Notice (SCN)	DI-E-3134

UNCLASSFIED

SECURITY CLASSIFICATION OF FORM
(highest classification of Title, Abstract, Keywords)

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in section 12.) Defence and Civil Institute of Environmental Medicine, 1133 Sheppard Ave West, P.O. Box 2000 North York, Ontario M3M 3B9	2. DOCUMENT SECURITY CLASSIFICATION (overall security classification of the document, including special warning terms if applicable) UNCLASSIFIED

3. DOCUMENT TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C,R or U) in parentheses after the title.)

THE APPLICATION OF HUMAN FACTORS ENGINEERING IN CF CCIS PROJECTS

4. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

DCIEM REPORT

5. AUTHOR(S) (Last name, first name, middle initial. If military, show rank, e.g. Doe, Maj. John E.)

BEEVIS, David
ESSENS, Peter
MACK, Ian

6. DOCUMENT DATE (month and year of publication of document) June 1994	7a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.) 50	7b. NO. OF REFS (total cited in document) 62

8a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant) DCIEM Project 51C5	8b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)
9a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.) DCIEM No. 94-33	9b. OTHER DOCUMENT NO.(S) (Any other numbers which may be assigned this document either by the originator or by the sponsor)

10. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

(X) Unlimited distribution
( ) Distribution limited to defence departments and defence contractors; further distribution only as approved
( ) Distribution limited to defence departments and Canadian defence contractors; further_distribution only as approved
( ) Distribution limited to government departments and agencies; further distribution only as approved
( ) Distribution limited to defence departments; further distribution only as approved
( ) Other

11. ANNOUNCEMENT AVAILABILITY (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availabilty (10). However, where further distribution (beyond the audience specified in 10) is possible, a wider announcement audience may be selected.)

12. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

Defence & Civil Institute of Environmental Medicine, 1133 Sheppard Ave West, P.O. Box 2000, North York, Ontario M3M 3B9

UNCLASSIFIED

SECURITY CLASSIFICATION OF FORM

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both offical languages unless the text is bilingual).

"The importance of integrating Human Factors Engineering with the development of Command, Control and Information Systems (CCIS) is discussed. It is recommended that a user-centred approach be taken to the development of such systems. The essential features of four software development approaches were reviewed. It was concluded that current approaches do not facilitate taking a user-centred approach, but new software system design methods provide may do so. The essential features of a user-centred approach are outlined, and the contribution of prototyping is reviewed. An existing Human Engineering Programme Plan, US MIL-STD-46855B, is modified to provide the basis for a plan for a user-centred approach in CCIS."

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible, keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Human Factors Engineering
Command and Control
Command, Control Information Systems